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Outline of Work for Standing Committees.

A. N. Talbot, Chairman; C. F. W. Felt, C. E. Lindsay, H. R. Safford.

Personnel of Committees.

L. A. Downs, Chairman; C. F. W. Felt, E. H. Fritch.

Special Committee on Manual.

Chas. S. Churchill, Chairman; W. B. Storey, Edwin F. Wendt, Robert Trimble, A. S. Baldwin.

Committee on Membership.

C. F. W. Felt, Chairman; R. N. Begien, E. H. Fritch.

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CHAS. S. CHURCHILL (*Senior Past-President—Chairman*), Assistant to President, Norfolk & Western Railway, Roanoke, Va.

EDWIN F. WENDT (*Past-President*), Member Engineering Board, Division of Valuation, Interstate Commerce Commission, Washington, D. C.

W. B. STOREY (*Past-President*), Vice-President, Atchison, Topeka & Santa Fe Railway System, Chicago, Ill.

ROBERT TRIMBLE (*Past-President*), Chief Engineer Maintenance of Way, Northwest System, Pennsylvania Lines, Pittsburgh, Pa.

A. S. BALDWIN (*Past-President*), Chief Engineer, Illinois Central Railroad, Chicago, Ill.

J. R. W. AMBROSE, Chief Engineer, Toronto Terminals Railway, Toronto, Ont., Canada.

GEO. H. BURGESS, Chairman, Valuation Committee, Delaware & Hudson Company, Albany, N. Y.

W. M. DAWLEY, Assistant Engineer, Erie Railroad, New York City.

V. K. HENDRICKS, Assistant Chief Engineer, St. Louis-San Francisco Railroad, St. Louis, Mo.

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CONSTITUTION.

REVISED AT THE FIFTH, EIGHTH AND TWELFTH ANNUAL CONVENTIONS

ARTICLE I.

NAME, OBJECT AND LOCATION.

Name.

1. The name of this Association is the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Object.

2. Its object is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

Means to Be Used.

3. The means to be used for this purpose shall be as follows:

(a) Meetings for the reading and discussion of reports and papers and for social intercourse.

(b) Investigation of matters pertaining to the objects of the Association through Standing and Special Committees.

(c) The publication of papers, reports and discussions.

(d) The maintenance of a library.

Responsibility.

4. Its action shall be recommendatory, and not binding upon its members.

Location of Office.

5. Its permanent office shall be located in Chicago, Ill., and the annual convention shall be held in that city.

ARTICLE II.

MEMBERSHIP.

Membership Classes.

1. The membership of this Association shall be divided into three classes, viz.: Members, Honorary Members and Associates.

Membership Qualifications.

(2) A Member shall be:

(a) Either a Civil Engineer, a Mechanical Engineer, an Electrical Engineer, or an official of a railway corporation, who has had not less

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than five (5) years' experience in the location, construction, maintenance or operation of railways, and who, at the time of application for membership, is engaged in railway service in a responsible position in charge of work connected with the Location, Construction, Operation or Maintenance of a Railway; provided, that all persons who were Active Members prior to March 20, 1907, shall remain Members except as modified by Article II, Clause 9.

(b) A Professor of Engineering in a college of recognized standing.

Honorary Membership Qualifications.

3. An Honorary Member shall be a person of acknowledged eminence in railway engineering or management. The number of Honorary Members shall be limited to ten.

Associate Membership Qualifications.

4. An Associate shall be a person not eligible as a Member, but whose pursuits, scientific acquirements or practical experience qualify him to co-operate with Members in the advancement of professional knowledge, such as Consulting, Inspecting, Contracting, Government or other Engineers, Instructors of Engineering in Colleges of recognized standing, and Engineers of Industrial Corporations when their duties are purely technical.

Membership Rights.

5. (a) Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights of Members, except that of holding office, and shall be exempt from the payment of dues.

(c) Associates shall have all the rights of Members, except those of voting and holding office.

Age Requirement.

6. An applicant to be eligible for membership in any class shall not be less than twenty-five (25) years of age.

"Railway" Defined.

7. The word "railway" in this Constitution means one operated by steam or electricity as a common carrier, dependent upon transportation for its revenue. Engineers of street railway systems and of railways which are used primarily to transport the material or product of an industry or industries to and from a point on a railway which is a common carrier, or those which are merely adjuncts to such industries, are eligible only as Associates.

Changes in Classes.

8. A Member, elected after March 20, 1907, who shall leave the railway service, shall cease to be a Member, but may retain membership in the Association as an Associate, subject to the provisions of Article II, Clause 9; provided, however, if he re-enters the railway service, he shall be restored to the class of Members.

Supply Men.

9. Persons whose principal duties require them to be engaged in the sale or promotion of railway patents, appliances or supplies, shall not be eligible for, nor retain membership in any class in this Association, except that those who were Active Members prior to March 20, 1907, may retain membership as Associates; provided, however, that anyone having held membership in the Association and subsequently having become subject to the operation of this clause, shall, if he again becomes eligible, be permitted to re-enter the Association, without the payment of a second entrance fee.

Transfers.

10. The Board of Direction shall transfer members from one class to another, or remove a member from the membership list, under the provisions of this Article.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

Charter Membership.

1. The Charter Membership consists of all persons who were elected before March 15, 1900.

Application for Membership.

2. The Charter Membership having been completed, any person desirous of becoming a member shall make application upon the form prescribed by the Board of Direction, setting forth in a concise statement his name, age, residence, technical education and practical experience. He shall refer to at least three members to whom he is personally known, each of whom shall be requested by the Secretary to certify to a personal knowledge of the candidate and his fitness for membership.

Election to Membership.

3. Upon receipt of an application properly endorsed, the Board of Direction, through its Secretary, or a Membership Committee selected from its own members, shall make such investigation of the candidate's

fitness as may be deemed necessary. The Secretary will furnish copies of the information obtained and of the application to each member of the Board of Direction. At any time, not less than thirty days after the filing of the application, the admission of the applicants shall be canvassed by letter-ballot among the members of the Board, and affirmative votes by two-thirds of its members shall elect the candidate; provided, however, that should an applicant for membership be personally unknown to three members of the Association, due to residence in a foreign country, or in such a portion of the United States as precludes him from a sufficient acquaintance with its members, he may refer to well-known men engaged in railway or allied professional work, upon the form above described, and such application shall be considered by the Board of Direction in the manner above set forth, and the applicant may be elected to membership by a unanimous vote of the Board.

Subscription to Constitution.

4. All persons, after due notice from the Secretary of their election, shall subscribe to the Constitution on the form prescribed by the Board of Direction. If this provision be not complied with within six months of said notice, the election shall be considered null and void.

Reinstatement.

5. Any person having been a member of this Association, and having, while in good standing, resigned such membership, may be reinstated without the payment of a second entrance fee; provided his application for reinstatement is signed by five members certifying to his fitness for same, and such application is passed by a two-thirds majority of the Board of Direction.

Honorary Membership.

6. Proposals for Honorary Membership shall be submitted by ten or more Members. Each member of the Board of Direction shall be furnished with a copy of the proposal, and if, after thirty days, the nominee shall receive the unanimous vote of said Board, he shall be declared an Honorary Member.

Expulsions.

7. When charges are preferred against a Member in writing by ten or more Members, the Member complained of shall be served with a copy of such charges, and he shall be called upon to show cause to the Board of Direction why he should not be expelled from the Association. Not less than thirty days thereafter a vote shall be taken on his expulsion, and he shall be expelled upon a two-thirds vote of the Board of Direction.

Resignations.

8. The Board of Direction shall accept the resignation, tendered in writing, of any Member whose dues are fully paid up.

ARTICLE IV.

DUES.

Entrance Fee.

1. An entrance fee of $10.00 shall be payable to the Association through its Secretary with each application for membership; and this sum shall be returned to the applicant if not elected.

Annual Dues.

2. *The annual dues are $10.00, payable during the first three months of the calendar year.

Arrears.

3. Any person whose dues are not paid before April 1st of the current year shall be notified of same by the Secretary. Should the dues not be paid prior to July 1st, the delinquent Member shall lose his right to vote. . Should the dues remain unpaid October 1st, he shall be notified on the form prescribed by the Board of Direction, and he shall no longer receive the publications of the Association. If the dues are not paid by December 31st, he shall forfeit his membership without further action or notice, except as provided for in Clause 4 of this Article.

Remission of Dues.

4. The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member who, from ill-health, advanced age or other good reasons, is unable to pay them.

ARTICLE V.

OFFICERS.

Officers.

1. The officers of the Association shall be Members and shall consist of:

A President,
A First Vice-President,
A Second Vice-President,
A Treasurer,
A Secretary,
Nine Directors,

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*The annual payment of $10.00 made by each member is to be subdivided and credited on the books of the Association, as follows: To member's subscription to the Bulletin, $5.00; annual dues, $5.00.

who, together with the five latest living Past-Presidents who are Members, shall constitute the Board of Direction in which the government of the Association shall be vested, and who shall act as Trustees, and have the custody of all property belonging to the Association.

Vice-Presidents' Priority.

2. The offices of First and Second Vice-Presidents shall be determined by the priority of their respective dates of election.

Terms of Office.

3. The terms of office of the several officers shall be as follows:

President, one year.
Vice-Presidents, two years.
Treasurer, one year.
Secretary, one year.
Directors, three years.

Officers Elected Annually.

4. (a) There shall be elected at each Annual Convention:

A President,
One Vice-President,
A Treasurer,
A Secretary,
Three Directors.

(b) The candidates for President and for Vice-President shall be selected from the members of the Board of Direction.

Conditions of Re-election of Officers.

5. The office of President shall not be held twice by the same person. A person who shall have held the office of Vice-President or Director shall not be eligible for re-election to the same office until at least one full term shall have elapsed after the expiration of his previous term of office.

Term of Officers.

6. The term of each officer shall begin with his election and continue until his successor is elected.

Vacancies in Offices.

7. (a) A vacancy in the office of President shall be filled by the First Vice-President.

(b) A vacancy in the office of either of the Vice-Presidents shall be filled by the Board of Direction by election from the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) Any other vacancies for the unexpired term in the membership of the Board of Direction shall be filled by the Board.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office he is holding; provided, however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provision of Article V, Clause 5.

Vacation of Office.

8. When an officer ceases to be a Member of the Association, as provided in Article II, his office shall be vacated, and be filled as provided in Article V, Clause 7.

Disability or Neglect.

9. In case of the disability or neglect in the performance of his duty, of an officer, the Board of Direction, by a two-thirds majority vote of the entire Board, shall have power to declare the office vacant, and fill it as provided in Article V, Clause 7.

ARTICLE VI.

NOMINATION AND ELECTION OF OFFICERS.

Nominating Committee.

1. (a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members not officers.

(b) The five Members shall be elected annually when the officers of the Association are elected.

Number of Candidates.

2. It shall be the duty of this Committee to nominate candidates to fill the offices named in Article V, and vacancies in the Nominating Committee caused by expiration of term of service, for the ensuing year, as follows:

Office to be Filled.	Number of Candidates to be named by Nominating Committee.	Number of Candidates to be Elected At Annual Election of Officers.
President	1	1
Vice-President	1	1
Treasurer	1	1
Secretary	1	1
Directors	9	3
Nominating Committee	10	5

Chairman.

3. The Senior Past-President shall act as permanent chairman of the Committee, and will issue the call for meetings. In his absence from meetings, the Past-President next in age of service shall act as Chairman pro tem. at the meeting.

Meeting of Committee.

4. Prior to December 1st each year, the Chairman shall call a meeting of the Committee at a convenient place and, at this meeting, nominees for office shall be agreed upon.

Announcement of Names of Nominees.

5. The names of the nominees shall be announced by the permanent Chairman to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

Additional Nominations by Members.

6. At any time between January 1st and February 1st, any ten or more Members may send to the Secretary additional nominations for the ensuing year signed by such Members.

Vacancies in List of Nominees.

7. If any person so nominated shall be found by the Board of Direction to be ineligible for the office for which he is nominated, or should a nominee decline such nomination, his name shall be removed and the Board may substitute another one therefor; and may also fill any vacancies that may occur in this list of nominees up to the time the ballots are sent out.

Ballots Issued.

8. Not less than thirty days prior to each Annual Convention, the Secretary shall issue ballots to each voting member of record in good standing, with a list of the several candidates to be voted upon, with the names arranged in alphabetical order when there is more than one name for any office.

Substitution of Names.

9. Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

Ballots.

10. (a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and may substitute another, at any time before the polls close.

Invalid Ballots.

11. Ballots not endorsed or from persons not qualified to vote shall not be opened; and any others not complying with the above provisions shall not be counted.

Closure of Polls.

12. The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by three tellers appointed by the Presiding Officer. The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

Requirements for Election.

13. The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

Tie Vote.

14. In case of a tie between two or more candidates for the same office, the members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

Announcement.

15. The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

First Nominating Committee.

16. Except as to the Past-Presidents, the first Nominating Committee and the three additional Directors provided for shall be appointed by the Board of Direction, one of the Directors for one year, one for two years and one for three years.

ARTICLE VII.

MANAGEMENT.

Duties of President.

1. (a) The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio member of all Committees, except the Nominating Committee.

(b) The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and discharge his duties in case of a vacancy in his office.

Duties of Treasurer.

2. The Treasurer shall receive all moneys and deposit same in the name of the Association, and shall receipt to the Secretary therefor. He shall invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. He shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

Duties of Secretary.

3. The Secretary shall be, under the direction of the President and Board of Direction, the Executive Officer of the Association. He shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. He shall see that the moneys due the Association are collected and without loss transferred to the custody of the Treasurer. He shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. He is to conduct the correspondence of the Association and keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

Auditing of Accounts.

4. The accounts of the Treasurer and Secretary shall be audited annually by a public accountant, under the direction of the Finance Committee of the Board.

Duties of Board.

5. The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

Board Meetings.

6. The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board.

Board Quorum.

7. Seven members of the Board shall constitute a quorum.

Board Committees.

8. At the first meeting of the Board after the Annual Convention, the following committees from its members shall be appointed by the

President, and shall report to and perform their duties under the supervision of the Board of Direction:

a. Finance Committee of three members.
b. Publication Committee of three members.
c. Library Committee of three members.
d. Outline of Work of Standing Committees of five members.

Duties of Finance Committee.

9. The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of moneys and as to other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by previous action and authority of the Board of Direction.

Duties of Publication Committee.

10. The Publication Committee shall have general supervision of the publications of the Association.

Duties of Library Committee.

11. The Library Committee shall have general supervision of the Library, the property therein, and the quarters occupied by the Secretary; shall make recommendations to the Board with reference thereto, and shall direct the expenditure for books and other articles of permanent value, from such sums as may be appropriated for these purposes.

Duties of Committee on Outline of Work of Standing Committees.

12. The Committee on Outline of Work of Standing Committees shall present a list of subjects for committee work during the ensuing year at the first meeting of the Board of Direction after the Annual Convention.

Standing Committees.

13. The Board of Direction may appoint such Standing Committees as it may deem best, to investigate, consider and report upon questions pertaining to railway location, construction or maintenance.

Special Committees.

14. Special Committees to examine into and report upon any subject connected with the objects of this Association may be appointed from time to time by the Board of Direction.

Discussion by Non-Members.

15. The Board of Direction may invite discussions of reports from persons not members of the Association.

Sanction of Acts of Board.

16. An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next Annual Convention of the Association shall be deemed to be the act of the Association, and shall not afterwards be impeached by any Member.

ARTICLE VIII.

MEETINGS.

Annual Convention.

1. The Annual Convention shall begin upon the third Tuesday in March of each year, and shall be held at such place in the City of Chicago as the Board of Direction may select.

Special Meetings.

2. Special meetings of the Association may be called by the Board of Direction, and special meetings shall be so called by the Board upon request of thirty Members, which request shall state the purpose of such meeting. The call for such meeting shall be issued not less than ten days in advance, and shall state the purpose and place thereof, and no other business shall be taken up at such meeting.

Notification of Annual Convention.

3. The Secretary shall notify all members of the time and place of the Annual Convention of the Association at least thirty days in advance thereof.

Association Quorum.

4. Twenty-five Members shall constitute a quorum at all meetings of the Association.

Order of Business.

5. (a) The order of business at annual conventions of the Association shall be as follows:

Reading of minutes of last meeting.
Address of the President.
Reports of the Secretary and Treasurer.
Reports of Standing Committees.
Reports of Special Committees.
Unfinished business.

New business.
Election of officers.
Adjournment.

(b) This order of business, however, may be changed by a majority vote of members present.

Rules of Order.

6. The proceedings shall be governed by "Robert's Rules of Order," except as otherwise herein provided.

Discussion.

7. Discussion shall be limited to members and to those invited by the presiding officer to speak.

ARTICLE IX.

AMENDMENTS.

Amendments.

1. Proposed amendments to this Constitution shall be made in writing and signed by not less than ten Members, and shall be acted upon in the following manner:

The amendments shall be presented to the Secretary, who shall send a copy of same to each member of the Board of Direction as soon as received. If at the next meeting of the Board of Direction a majority of the entire Board are in favor of considering the proposed amendments, the matter shall then be submitted to the Association for letter-ballot, and the result announced by the Secretary at the next Annual Convention. In case two-thirds of the votes received are affirmative, the amendments shall be declared adopted and become immediately effective.

GENERAL INFORMATION.

(Subject to change from time to time by Board of Direction.)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS.

(A) APPOINTMENT OF COMMITTEES AND OUTLINE OF WORK.

Standing Committees.

1. The following are Standing Committees:

I. Roadway.
II. Ballast.
III. Ties.
IV. Rail.
V. Track.
VI. Buildings.
VII. Wooden Bridges and Trestles.
VIII. Masonry.
IX. Signs, Fences and Crossings.
X. Signals and Interlocking.
XI. Records and Accounts.
XII. Rules and Organization.
XIII. Water Service.
XIV. Yards and Terminals.
XV. Iron and Steel Structures.
XVI. Economics of Railway Location.
XVII. Wood Preservation.
XVIII. Electricity.
XIX. Conservation of Natural Resources.
XX. Uniform General Contract Forms.
XXI. Economics of Railway Operation.
XXII. Economics of Railway Labor.

Special Committees.

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Clause 14, of the Constitution.

Personnel of Committees.

3. The personnel of all Committees will continue from year to year, except when changes are announced by the Board of Direction. Ten per cent. of the membership of each Committee shall be changed each year.

Members of committees who do not attend meetings of committees during the year or render service by correspondence will be relieved and the vacancies filled by the Board at the succeeding Annual Convention.

Outline of Work.

4. As soon as practicable after each Annual Convention the Board of Direction will assign to each Committee the important questions which, in its judgment, should preferably be considered during the current year. Committees are privileged to present the results of any special study or investigation they may be engaged upon or that may be considered of sufficient importance to warrant presentation.

(B) PREPARATION OF COMMITTEE REPORTS.

General.

5. The collection and compilation of data and subsequent analysis in the form of arguments and criticism is a necessary and valuable preliminary element of committee-work.

Collection of Data.

6. Committees are privileged to obtain data or information in any proper way. If desired, the Secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

Plan of Reports.

7. Committee reports should be prepared as far as practicable to conform to the following general plan:

(a) It is extremely important that every Committee should examine its own subject-matter in the "Manual" prior to each Annual Convention, and revise and supplement it, if deemed desirable, giving the necessary notice of any recommended changes in accordance with Clause 6 (a) of the General Rules for the Publication of the "Manual." If no changes are recommended, statement should be made accordingly.

(b) When deemed necessary, the previous report should be reviewed.

(c) Subjects presented in previous reports on which no action was taken should be resubmitted, stating concisely the action desired. It may not be necessary to repeat the original text in the report, reference to former publication being sufficient, unless changes in the previously published version are extensive. Minor changes can be explained in the text of the report.

Definitions.

(d) Technical terms used in the report, the meaning of which is not clearly established, should be defined, but defined only from the standpoint of railway engineering.

History.

(e) If necessary, a brief history of the subject-matter under discussion, with an outline of its origin and development, should be given.

Analysis.

(f) An analysis of the most important elements of the subject-matter should be given.

Argument.

(g) The advantages and disadvantages of the present and recommended practices should be set forth.

Illustrations.

(h) Illustrations accompanying reports should be prepared so that they can be reproduced on one page. The use of folders should be avoided as much as possible, on account of the increased expense and inconvenience in referring to them. Plans showing current practice, or necessary for illustration, are admissible, but those showing proposed definite design or practice should be excluded. Recommendations should be confined to governing principles.

Illustrations should be made on tracing cloth with heavy black lines and figures, so as to stand a two-thirds reduction; for example: To come within a type page (4 inches by 7 inches), the illustration should be made three times the above size.

To insure uniformity, the one-stroke, inclined Gothic lettering is recommended.

Photographs should be clear and distinct silver prints.

Conclusions.

(i) The conclusions of the Committee which are recommended for publication in the Manual should be stated in concise language, logical sequence, and grouped together, setting forth the principles, specifications, definitions, forms, tables and formulas included in the recommendation. Portions of the text of the report which are essential to a clear interpretation and understanding of the conclusions, should be included as an integral part thereof.

(c) PUBLICATION OF COMMITTEE REPORTS.

Reports Required.

8. (a) Reports will be required from each of the Standing and Special Committees each year.

(b) Although several subjects may be assigned to each Committee by the Board of Direction, a full report on only one subject is expected at each Annual Convention, but the preliminary work on some of the remaining subjects should be in progress, and, when deemed advisable, partial reports of progress should also be presented. This method allows time for their proper preparation and consideration.

Date of Filing Reports.

9. Committee reports to come before the succeeding convention for discussion should be filed with the Secretary not later than November 30th of each year.

10. Committees engaged upon subjects involving an extended investigation and study are privileged to present progress reports, giving a brief statement of the work accomplished, and, if deemed expedient, a forecast of the final report to be presented.

Publication of Reports.

11. Committee reports will be published in the Bulletin in such sequence as the Board of Direction may determine, for consideration at the succeeding convention. Reports will be published in the form presented by the respective Committees. Alterations ordered by the convention will be printed as an appendix to the report.

Written Discussions.

12. Committees should endeavor to secure written discussions of published reports. Written discussions will be transmitted to the respective Committees, and if deemed desirable by the Committee, the discussions will be published prior to the convention and be considered in connection with the report.

Verbal Discussions.

13. Each speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

Sequence. (D) CONSIDERATION OF COMMITTEE REPORTS.

14. The sequence in which Committee reports will be considered by the convention will be determined by the Board of Direction.

Method.

15. The method of consideration of Committee reports will be one of the following:

(a) Reading by title.
(b) Reading, discussing and acting upon each conclusion separately.
(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

Final Action.

16. Action by the convention on Committee reports will be one of the following, after discussion is closed:

(a) Receiving as information.
(b) Receiving as a progress report.
(c) Adoption of a part complete in itself and referring remainder back to Committee.
(d) Adoption as a whole.
(e) Recommittal with or without instructions.
(f) Adoption as a whole.
(g) Recommendation to publish in the Manual.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the Committee considers affected.

The Chair will decline to entertain amendments which in his opinion lie entirely within the duties of the Editor.

(E) PUBLICATION BY TECHNICAL JOURNALS.

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the Bulletin; provided, application therefor is made in writing and proper credit be given the Association, authors or Committees presenting such material.

GENERAL RULES FOR THE PUBLICATION OF THE "MANUAL."

Title.

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall edit the Manual and shall have authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Adoption of Reports Not Binding.

3. Matters adopted by the Association and subsequently published in the Manual shall be considered in the direction of good practice, but shall not be binding on the members.

Contents.

4. The Manual will only include conclusions relating to definitions, specifications and principles of practice as have been made the subject of a special study by a Standing or Special Committee and embodied in a Committee report, published not less than thirty days prior to the Annual Convention, and submitted by the Committee to the Annual Convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction, should be reviewed by the American Railway Association, may be referred to that Association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the Committee report and subsequent discussion and the final action of the Association.

Revision.

6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent Annual Convention, provided such changes are proposed in time for publication not less than thirty days prior to the Annual Convention, and in the following manner: (a) Upon recon-

mendation of the Committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. The Manual will be revised either by publishing a new edition or a supplemental pamphlet as promptly as possible after each Annual Convention.

American Railway Engineering Association

VOL. 18, No. 196 . . . . JUNE, 1917

FOREWORD

To the Members of the Association:

The Board of Direction has prepared the "General Rules for the Preparation, Publication and Consideration of Committee Reports," and the "Outline of Work" for the guidance of the several Committees, and their careful study in advance is urged, in order to improve and facilitate the work of the Association.

JOHN G. SULLIVAN, President.

OUTLINE OF COMMITTEE WORK FOR 1917

SPECIAL NOTICE TO COMMITTEES.

Observe "General Rules for the Preparation, Publication and Consideration of Committee Reports," on pp. 16-20. It is not desired that all subjects be reported upon this year. The number to be reported upon should be determined after careful estimate of the length of the report and the time required by the convention for its consideration. Two subjects will be the maximum for the action of the convention, unless otherwise directed by the Board of Direction.

Make concise recommendations for next year's work.

COMMITTEE I.

ROADWAY.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Subsidence under Embankments.—Methods of determining extent, character and effect.

3. Shrinkage of Embankments.—Select a number of specific instances reciting all the conditions, such as locality, weather, foundation, character of filling material, height of fill, method of construction, etc., to be used as a guide in estimating shrinkage.

4. Report on prevention or cure of water pockets in roadbed.

5. Continue the study of unit pressures allowable on roadbeds of different materials, coöperating with Special Committee on Stresses in Railroad Track.

6. Consider and report on the best method for draining roadway through stations and yards.

PERSONNEL.

W. M. Dawley (*Chairman*), Assistant Engineer, Erie Railroad, New York City.

J. A. Spielmann (*Vice-Chairman*), Assistant to General Superintendent, Baltimore & Ohio Railroad, Pittsburgh, Pa.

J. R. W. Ambrose, Chief Engineer, Toronto Terminals Company, Toronto, Canada.

H. E. Astley, Superintendent, New York, New Haven & Hartford Railroad, Boston, Mass.

C. W. Brown, Superintendent, Lehigh & New England Railroad, South Bethlehem, Pa.

S. P. Brown, Chief Engineer, Mount Royal Tunnel & Terminal Company, Montreal, Canada.

B. M. Cheney, General Inspector of Permanent Way, Chicago, Burlington & Quincy Railroad, Chicago, Ill.

C. W. Cochran, Engineer Maintenance of Way, Cleveland, Cincinnati, Chicago & St. Louis Railway, Galion, Ohio.

W. C. Curd, Contracting Engineer, Lane & Bowler Company, Memphis, Tenn.

Paul Didier, Principal Assistant Engineer, Baltimore & Ohio Railroad, Pittsburgh, Pa.

S. B. Fisher, Missouri, Kansas & Texas Railway, Parsons, Kan.

W. C. Kegler, Engineer Maintenance of Way, Cleveland, Cincinnati, Chicago & St. Louis Railway, Galion, Ohio.

L. F. Lonnbladh, Chief Engineer, Missouri, Kansas & Texas Railway, Dallas, Texas.

H. W. McLeod, Assistant Engineer, Canadian Pacific Railway, Winnipeg, Man., Can.

C. M. McVay, Engineer Maintenance of Way, Kanawha & Michigan Railway, Charleston, W. Va.

F. M. Patterson, Senior Civil Engineer, Interstate Commerce Commission, Chicago, Ill.

W. H. Petersen, Engineer Maintenance of Way, Chicago, Rock Island & Pacific Railway, Des Moines, Iowa.

P. Petri, District Engineer, Baltimore & Ohio Railroad, Pittsburgh, Pa.

W. F. Purdy, Chief Engineer, Pittsburgh & West Virginia Railway, Pittsburgh, Pa.

R. A. Rutledge, Chief Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kan.

W. H. Sellew, Valuation Department, Michigan Central Railroad, Detroit, Mich.

J. M. Sills, District Engineer, St. Louis-San Francisco Railroad, Springfield, Mo.

G. R. Talcott, Resident Engineer, Atchison, Topeka & Santa Fe Railway, Shattuck, Okla.

W. P. Wiltsee, Assistant to Chief Engineer, Norfolk & Western Railway, Roanoke, Va.

COMMITTEE II.

BALLAST.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on ballast sections, with particular reference to sub- and top-ballast.

3. Report on the proper depth of ballast of various kinds to insure uniform distribution of loads on the roadbed, conferring with Special Committee on Stresses in Railroad Track and Committee on Roadway.

4. Report on methods and cost of applying ballast, with especial reference to the following plans:

(a) Organization of the most economical ballast gang of railway company forces.

(b) Use and limitations of mechanical tools, such as the pneumatic tamper and the spreader for forming shoulder and path.

(c) Application by contract.

5. Report on the comparative merit of different stones and gravel and other material for ballast.

6. Report on the different kinds of physical tests of ballast (chemical also, if necessary), and the manner of conducting them, and recommend the tests which are considered necessary and sufficient to form a guide for comparing the suitability of various stones and other material for ballast.

PERSONNEL.

H. E. Hale (*Chairman*), Group Engineer, Presidents' Conference Committee on Valuation, New York City.

J. M. Meade (*Vice-Chairman*), Special Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kansas.

C. W. Baldridge, Assistant Engineer, Santa Fe Railway, Chicago, Ill.

J. S. Bassett, Assistant Engineer, Missouri Pacific Railroad, Monroe, La.

W. J. Bergen, Assistant to Chief Engineer, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

H. E. Boardman, Assistant Engineer, Valuation Department, New York Central Railroad, New York City.

C. J. Coon, Engineer Maintenance of Way, Grand Central Terminal, New York City.

T. W. Fatherson, Engineer Maintenance of Way, Chicago Great Western Railroad, Des Moines, Iowa.

G. H. Harris, Engineer Maintenance of Way, Michigan Central Railroad, Detroit, Mich.

F. A. Jones, General Roadmaster, Missouri Pacific Railroad, Wynne, Ark.

J. S. McBride, Principal Assistant Engineer, Chicago & Eastern Illinois Railroad, Chicago, Ill.

William McNab, (*Past-President*), Valuation Engineer, Grand Trunk Railway, Montreal, Canada.

F. J. Parrish, Division Engineer, Cincinnati, Hamilton & Dayton Railway, Dayton, Ohio.

S. B. Rice, Engineer Maintenance of Way, Richmond, Fredericksburg & Potomac Railroad, Richmond, Va.

H. L. Ripley, Valuation Engineer, New York, New Haven & Hartford Railroad, Boston, Mass.

H. E. Stansbury, Resident Engineer, El Paso & Southwestern System, Tucumcari, N. M.

Paul Sterling, Maintenance Engineer, New York, New Haven & Hartford Railroad, Lines West, New Haven, Conn.

F. J. Stimson, Superintendent, Pennsylvania Lines, Richmond, Ind.

D. W. Thrower, Assistant Valuation Engineer, Illinois Central Railroad, Chicago, Ill.

W. Trapnell, Chief Engineer, Coal & Coke Railway, Elkins, W. Va.

D. L. Sommerville, Superintendent, New York Central Railroad, East of Buffalo, Albany, N. Y.

W. K. Walker, Engineer Maintenance of Way, Wabash Railway, Montpelier, Ohio.

R. C. White, Superintendent, Missouri Pacific Railroad, Wynne, Ark.

W. D. Williams, Chief Engineer, Cincinnati Northern Railroad, Van Wert, Ohio.

COMMITTEE III.

TIES.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Continue the study of effect of design of tie plates and track spikes on the durability of cross-ties.

3. Report on methods in use by various railways for controlling tie renewals.

4. Recommend proper dimensions for cross-ties.

5. Report results of investigation of Forms M. W. 301, 302, 303 and 305, Statistics of Cross-Ties, to see if they are in general use on membership lines.

6. Report on trials of substitute ties.

PERSONNEL.

F. R. Layng (*Chairman*), Engineer of Track, Bessemer & Lake Erie Railroad, Greenville, Pa.

H. S. Wilgus (*Vice-Chairman*), Engineer Maintenance of Way, Pittsburg, Shawmut & Northern Railroad, Angelica, N. Y.

C. C. Albright, Associate Professor of Civil Engineering, Purdue University, Lafayette, Ind.

W. C. Baisinger, Assistant Engineer on Construction, Santa Fe Railway, Chicago, Ill.

Theo. Bloecher, Jr., Division Engineer, Baltimore & Ohio Railroad, Philadelphia, Pa.

F. Boardman, Division Engineer; Electric Division, New York Central Railroad, New York City.

W. J. Burton, Assistant Engineer, Missouri Pacific Railroad, St. Louis, Mo.

W. A. Clark, Chief Engineer, Duluth & Iron Range Railroad, Duluth, Minn.

S. B. Clement, Chief Engineer, Temiskaming & Northern Ontario Railway, North Bay, Ont.

E. L. Crugar, District Engineer, Illinois Central Railroad, New Orleans, La.

L. A. Downs (*Director*), General Superintendent, Illinois Central Railroad, New Orleans, La.

G. F. Hand, Assistant Engineer, New York, New Haven & Hartford Railroad, New Haven, Conn.

L. C. Hartley, Chief Engineer, Chicago & Eastern Illinois Railroad, Chicago, Ill.

E. D. Jackson, Assistant Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

J. B. Myers, District Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

A. J. NEAFIE, Principal Assistant Engineer, Delaware, Lackawanna & Western Railroad, Hoboken, N. J.

R. R. PAINE, Assistant Engineer, Union Pacific Railroad, Omaha, Neb.

G. P. PALMER, Division Engineer, Baltimore & Ohio Chicago Terminal Railroad, Chicago, Ill.

LOUIS YAGER, Engineer Maintenance of Way, Northern Pacific Railway, St. Paul, Minn.

COMMITTEE IV.

RAIL.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, giving special attention to the rail designs recently adopted and to the specifications for carbon steel rails and joint bars.

2. Report on rail failures and present statistics and conclusions as to causes and submit suggestions for improvement.

3. Continue special investigation of rails.

4. Report on track bolts and nutlocks.

5. (a) Report on details of manufacture and mill practice as they affect rail quality.

(b) Continue research on the possibility of various improvements in methods of manufacture of steel rails.

6. Make critical study of joint bars from the standpoint of design and material, together with laboratory tests, including strain-gage measurements after having established a uniform method for comparative testing.

7. Report on relative value of material for joint bars, quenched only versus quenched and tempered, and whether it is most advantageous to quench in oil or water, submitting specifications therefor.

8. Report on rational relation between intensity of pressure due to wheel loads and resistance of rail steel to crushing and deformation.

9. Continue investigation and development of methods of inspection.

10. Report on Federal and State Commission rulings.

PERSONNEL.

JOHN D. ISAACS (*Chairman*), Consulting Engineer, Southern Pacific Company, New York City.

R. MONTFORT (*Vice-Chairman*), Consulting Engineer, Louisville & Nashville Railroad, Louisville, Ky.

E. E. ADAMS, Consulting Engineer, Union Pacific Railroad, New York City.

E. B. ASHBY, Consulting Engineer, Lehigh Valley Railroad, New York City.

J. A. ATWOOD (*Director*), Chief Engineer, Pittsburgh & Lake Erie Railroad, Pittsburgh, Pa.

A. S. Baldwin (*Past-President*), Chief Engineer, Illinois Central Railroad, Chicago, Ill.

W. C. Barnes, Assistant Consulting Engineer, Southern Pacific Company, New York City.

Chas. S. Churchill (*Past-President*), Assistant to President, Norfolk & Western Railway, Roanoke, Va.

W. C. Cushing (*Past-President*), Chief Engineer Maintenance of Way, Pennsylvania Lines, Pittsburgh, Pa.

G. M. Davidson, Chemist and Engineer of Tests, Chicago & Northwestern Railway, Chicago, Ill.

Dr. P. H. Dudley, Consulting Engineer, New York Central Lines, New York City.

J. M. R. Fairbairn, Assistant Chief Engineer, Canadian Pacific Railway, Montreal, Canada.

L. C. Fritch (*Past-President*), General Manager, Seaboard Air Line Railway, Norfolk, Va.

A. W. Gibbs, Chief Mechanical Engineer, Pennsylvania Railroad, Philadelphia, Pa.

Howard G. Kelley (*Past-President*), Acting-President, Grand Trunk Railway System, Montreal, Canada.

C. F. Loweth, Chief Engineer, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill.

H. B. MacFarland, Engineer of Tests, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

C. A. Morse (*First Vice-President*), Chief Engineer, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

A. W. Newton, Chief Engineer, Chicago, Burlington & Quincy Railroad, Chicago, Ill.

J. R. Onderdonk, Engineer of Tests, Baltimore & Ohio Railroad, Baltimore, Md.

G. J. Ray, Chief Engineer, Delaware, Lackawanna & Western Railroad, Hoboken, N. J.

H. R. Safford (*Director*), Chief Engineer, Grand Trunk Railway System, Montreal, Canada.

J. P. Snow, Consulting Engineer, Boston, Mass.

F. S. Stevens, Engineer Maintenance of Way, Philadelphia & Reading Railway, Reading, Pa.

Earl Stimson (*Second Vice-President*), Engineer Maintenance of Way, Baltimore & Ohio Railroad, Baltimore, Md.

R. Trimble (*Past-President*), Chief Engineer Maintenance of Way, Pennsylvania Lines, Pittsburgh, Pa.

M. H. Wickhorst, Engineer of Tests, Rail Committee, Chicago, Ill.

COMMITTEE V.

TRACK.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on typical plans of turnouts, crossovers, slip-switches and double crossovers, and prepare detail plans for such work, including such incidentals as tie plates, rail braces, riser plates, etc., conferring with Committee on Signals and Interlocking.

3. Report on reduction of taper of tread of wheel to 1 in 38 and on canting the rail inward.

4. Report on test of tie plates subject to brine drippings.

5. Report on specifications for relayer rail for various uses.

6. Consider the advisability of reducing allowable flat spots on freight car wheels, collecting data as to damage done by flat spots.

7. Consider design of cut track spikes.

8. Report upon the effect of fast trains upon the cost of maintenance of way and equipment.

9. Report on whether widening of the flange of the wheels would not be detrimental to the present standard of track construction.

10. Report on guard rails and flangeways and effect of increase of one-eighth-inch thickness of wheel flanges.

PERSONNEL.

G. J. Ray (*Chairman*), Chief Engineer, Delaware, Lackawanna & Western Railroad, Hoboken, N. J.

J. R. Leighty (*Vice-Chairman*), Engineer Maintenance, Missouri Pacific Railroad, Kansas City, Mo.

M. C. Blanchard, Engineer, Eastern District, Atchison, Topeka & Santa Fe Railway, Topeka, Kansas.

Geo. H. Bremner (*Treasurer*), District Engineer, Interstate Commerce Commission, Chicago, Ill.

H. M. Church, Division Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

Garrett Davis, Assistant Engineer, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

A. L. Grandy, Assistant General Manager, Pere Marquette Railroad, Detroit, Mich.

G. W. Hegel, Chief Engineer, Chicago Junction Railway, Chicago, Ill.

T. H. Hickey, Inspector of Maintenance of Way, Michigan Central Railroad, Detroit, Mich.

T. T. Irving, Division Engineer, Grand Trunk Railway, Chicago, Ill.

J. B. Jenkins, Valuation Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

H. A. Lloyd, Special Agent, Erie Railroad, Jersey City, N. J.

F. H. McGuigan, Jr., Assistant Engineer, Grand Trunk Railway, Montreal, Canada.

J. V. Neubert, Engineer of Track, New York Central Railroad, New York City.

R. M. Pearce, Resident Engineer, Pittsburgh & Lake Erie Railroad, Pittsburgh, Pa.

C. D. Perkins, Assistant to Engineer Maintenance of Way, New York, New Haven & Hartford Railroad, New Haven, Conn.

H. T. Porter, Chief Engineer, Bessemer & Lake Erie Railroad, Greenville, Pa.

Thos. Quigley, Roadmaster, Illinois Central Railroad, McComb, Miss.

J. B. Strong, Vice-President, Ramapo Iron Works, Hillburn, N. Y.

W. P. Wiltsee, Assistant to Chief Engineer, Norfolk & Western Railway, Roanoke, Va.

COMMITTEE VI.

BUILDINGS.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, with especial reference to appropriate definitions.
2. Report on coaling stations.
3. Report on freight-house and passenger station scales.
4. Report on ash pits.
5. Report on a classification of buildings on the basis of "Specification Types," and upon the use of the "cubic foot," "square foot" and "bill of particulars" methods for ascertaining the approximate cost of new construction.
6. Report on safety-tread devices for stations exposed to the elements.
7. Report on the general subject of roadway buildings.
8. Report on design and merits of high and low platforms at passenger stations.
9. Report on design of shop buildings.
10. Report on comparison of "umbrella" versus "butterfly" sheds at through stations.

PERSONNEL.

M. A. Long (*Chairman*), Assistant to Chief Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

G. H. Gilbert (*Vice-Chairman*), Engineer Bridges and Buildings, Southern Railway, Western Lines, Cincinnati, Ohio.

G. W. Andrews, Assistant to Engineer Maintenance of Way, Baltimore & Ohio Railroad, Baltimore, Md.

D. R. Collin, Architect, Third National Bank Building, Syracuse, N. Y.

W. H. Cookman, Architect, Pennsylvania Railroad, Philadelphia, Pa.

C. G. Delo, Chief Engineer, Chicago Great Western Railroad, Chicago, Ill.

W. T. Dorrance, Chief Draftsman, New York, New Haven & Hartford Railroad, New Haven, Conn.

K. B. Duncan, Valuation Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kan.

C. H. Fake, Engineer Maintenance of Way, Mississippi River & Bonne Terre Railway, Bonne Terre, Mo.

A. T. Hawk, Architect, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

F. F. Harrington, Engineer Structures, Virginian Railway, Norfolk, Va.

E. A. Harrison, Architect, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

A. Larsen, Resident Engineer, Southern New England Railroad, Providence, R. I.

J. W. Orrock, Principal Assistant Engineer, Canadian Pacific Railway, Montreal, Canada.

S. B. Phillips, Assistant Engineer, Union Pacific System, Portland, Ore.

R. V. Reamer, Engineer Maintenance of Way, Central Railroad of New Jersey, Jersey City, N. J.

C. W. Richey, Master Carpenter, Pennsylvania Railroad, Pittsburgh, Pa.

John Schofield, Architect, Canadian Northern Railway, Winnipeg, Man.

Z. H. Sikes, Assistant Engineer of Structures, New York Central Railroad, New York City.

W. J. Watson, Civil and Architectural Engineer, Cleveland, Ohio.

COMMITTEE VII.

WOODEN BRIDGES AND TRESTLES.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on design of docks and wharves; coal and ore wharves, including various details, such as bulkheads, cribwork, dry docks, ferry slips, jetties, jetty inclines and the necessary machinery, conveyors and fixtures for the economical operation of property of this character.

3. Report on comparative merits and economic features of ballast deck and reinforced concrete trestles, taking into consideration the design of ballast floors for timber trestles, and collecting data as to costs of various types of each class of structure.

4. Continue the study of the use of lag screws in trestle construction.

PERSONNEL.

E. A. Frink (*Chairman*), Principal Assistant Engineer, Seaboard Air Line Railway, Norfolk, Va.

W. H. Hoyt (*Vice-Chairman*), Assistant Chief Engineer, Duluth, Missabe & Northern Railroad, Duluth, Minn.

H. Austill, Bridge Engineer, Mobile & Ohio Railroad, Mobile, Ala.

F. Auryansen, Bridge Engineer, Long Island Railroad, Jamaica, N. Y.

H. C. Brown, Jr., 37 West Van Buren Street, Chicago, Ill.

A. D. Case, Engineer Structures, Boston & Albany Railroad, Boston, Mass.

A. H. **Freygang**, Division Engineer, Baltimore & Ohio Southwestern Railroad, Seymour, Ind.

E. A. **Hadley**, Chief Engineer, Missouri Pacific Railroad, St. Louis, Mo.

G. A. **Haggander**, Bridge Engineer, Chicago, Burlington & Quincy Railroad, Chicago, Ill.

F. F. **Hanly**, Division Engineer, Baltimore & Ohio Railroad, Cumberland, Md.

H. T. **Hazen**, District Engineer, Canadian Northern Railway, Toronto, Ont., Canada.

C. S. **Heritage**, Bridge Engineer, Kansas City Southern Railway, Kansas City, Mo.

A. O. **Ridgway**, Assistant Chief Engineer, Denver & Rio Grande Railroad, Denver, Colo.

F. S. **Schwinn**, Assistant Superintendent, International & Great Northern Railroad, Palestine, Texas.

C. S. **Sheldon**, Engineer Bridges and Structures, Pere Marquette Railroad, Detroit, Mich.

I. L. **Simmons**, Bridge Engineer, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

D. W. **Smith**, Valuation Engineer, Hocking Valley Railway, Columbus, Ohio.

A. M. **Van Auken**, Assistant Engineer Costs, Michigan Central Railroad, Detroit, Mich.

W. H. **Vance**, Engineer Maintenance of Way, St. Louis Southwestern Railway, Tyler, Tex.

D. R. **Young**, Assistant Engineer, Delaware, Lackawanna & Western Railroad, Buffalo, N. Y.

COMMITTEE VIII.

MASONRY.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. (a) Report on cost and method of constructing concrete piles, and make recommendations on how and where to be used.

(b) Present additional typical designs for concrete piles for different loading, and rules for driving under various conditions and loading.

3. Continue study of typical designs of foundations for piers, abutments, retaining walls and arches in various soils and depth of water (not including pneumatic foundations).

4. Report upon the wisdom of the use of blast furnace slag in reinforced concrete work, taking into especial consideration its probable duration.

5. Report on designs and recommended specifications for construction of concrete culvert pipe.

PERSONNEL.

F. L. **Thompson** (*Chairman*), Assistant Chief Engineer, Illinois Central Railroad, Chicago, Ill.

J. J. **Yates** (*Vice-Chairman*), Bridge Engineer, Central Railroad of New Jersey, New York City.

R. **Armour**, Masonry Engineer, Grand Trunk Railway, Montreal, Canada.

John C. **Beye**, Locating Engineer, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

G. E. **Boyd**, Division Engineer, Delaware, Lackawanna & Western Railroad, Buffalo, N. Y.

H. A. **Cassil**, Engineer Maintenance of Way, Pere Marquette Railroad, Detroit, Mich.

C. S. **Coe**, Engineer Maintenance of Way, Florida East Coast Railway, St. Augustine Fla.

T. L. **Condron**, Consulting Engineer, Monadnock Block, Chicago, Ill.

J. K. **Conner**, Chief Engineer, Lake Erie & Western Railroad, Indianapolis, Ind.

C. S. **Davis**, Structural Engineer, Pennsylvania Lines, Detroit, Mich.

J. L. **Harrington**, Consulting Engineer, Kansas City, Mo.

W. K. **Hatt**, Professor of Civil Engineering, Purdue University, Lafayette, Ind.

L. J. **Hotchkiss**, Consulting Engineer, Chicago, Ill.

Richard L. **Humphrey**, Consulting Engineer and Chemist, Philadelphia, Pa.

Noah **Johnson**, Engineer Maintenance of Way, Wabash Railway, Peru, Ind.

M. S. **Ketchum**, Professor of Civil Engineering, University of Colorado, Boulder, Colo.

W. M. **Kinney**, Inspecting Engineer, Universal Portland Cement Company, Chicago, Ill.

W. S. **Lacher**, Associate Engineering Editor, Railway Age Gazette, Chicago, Ill.

A. E. **Owen**, Chief Engineer, Central Railroad of New Jersey, New York City.

W. M. **Ray**, Assistant Engineer, Baltimore & Ohio Railroad, Cleveland, Ohio.

C. P. **Richardson**, Assistant Engineer, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

G. H. **Scribner, Jr.**, Contracting Engineer, Chicago, Ill.

F. P. **Sisson**, Assistant Engineer, Grand Trunk Railway, Detroit, Mich.

J. E. **Smith**, Assistant Professor, Civil Engineering, University of Illinois, Urbana, Ill.

Job **Tuthill**, Chief Engineer, Pere Marquette Railroad, Detroit, Mich.

B. A. **Underwood**, Resident Engineer, Southern New England Railroad, Webster, Mass.

COMMITTEE IX.

SIGNS, FENCES AND CROSSINGS.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, taking into special consideration the subject of flangeways, both when the street or highway is or is not occupied by street or interurban railway tracks.

2. Report on subject of "Signs," and the principles of design and rules for their use, considering the adoption of a standard sign for general use, as far as possible. Study in this connection, in collaboration with Committee on Signals and Interlocking, the design of suitable day and night (if necessary) marks or signs for switch signals, derail switches, stop posts, slow posts, resume-speed posts, water-station and track-pan markers, highway crossing signals, etc. Also consider the location of signs, having in mind the matter of safety of employés obliged to use the roadway.

4. Report on legal requirements relative to the provision of fences for right-of-way and of stock-guards.

5. Report on classification of fences into "types."

6. Make a comprehensive study of crossings:

(a) Grade crossings:
Crossing gates:
Crossing signal bells;
Warning signals.

(b) Over- and under-grade crossings:

Study the laws and requirements of the Federal Government of the various States, Provinces or municipalities which affect the distribution of cost as between the carrier and the public.

7. Make a careful investigation of all styles of manufactured parts that have been in use long enough to warrant any conclusion as to their durability, with particular attention to:

(a) A study of various types of end or strain posts used with steel fence posts, with a view to recommending a type which would be a satisfactory substitute for posts set in concrete, the cost of which is high in those now in use.

(b) An investigation as to the best method of bracing concrete end or strain posts.

(c) A further study of the subject of concrete fence posts now in use by various railroads.

8. Submit a revised analysis of the comparative annual cost of fences, using wood, metal and concrete posts, with a view to bringing this subject, considered by the Committee in 1912, up to date.

PERSONNEL.

W. F. Strouse (*Chairman*), Assistant Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

Arthur Crumpton (*Vice-Chairman*), Assistant Valuation Engineer, Grand Trunk Railway, Montreal, Canada.

F. D. Batchellor, District Engineer, Cincinnati, Hamilton & Dayton Railroad, Cincinnati, Ohio.

H. E. Billman, General Roadmaster, Missouri Pacific Railroad, St. Louis, Mo.

C. G. Bryan, Valuation Department, Illinois Central Railroad, Chicago.

G. F. Black, Engineer Maintenance of Way, Maine Central Railroad, Portland, Me.

A. S. Butterworth, Assistant Engineer, Missouri Pacific Railroad, St Louis, Mo.

A. C. Copland, Office Engineer, Chesapeake & Ohio Railway, Richmond, Va.

B. J. Dalton, Chairman, Valuation Committee, Missouri, Kansas & Texas Railway, Parsons, Kansas.

F. T. Darrow, Engineer Maintenance of Way, Chicago, Burlington & Quincy Railroad, Lincoln, Neb.

G. N. Edmondson, Division Engineer, New York Central Railroad, Rochester, N. Y.

R. C. Gowdy, Chief Engineer, Fort Worth & Denver City Railroad, Fort Worth, Texas.

Paul Hamilton, Engineer Track and Roadway, Cleveland, Cincinnati, Chicago & St. Louis Railway, Cincinnati, Ohio.

Maro Johnson, Assistant Engineer, Illinois Central Railroad, Chicago.

L. C. Lawton, Division Engineer, Atchison, Topeka & Santa Fe Railway, Newton, Kansas.

S. L. McClanahan, Division Engineer, Chicago, Rock Island & Pacific Railway, Goodland, Kansas.

L. A. Mitchell, Superintendent, Union Traction Company of Indiana, Anderson, Ind.

T. E. Rust, Chief Engineer, Waterloo, Cedar Falls & Northern Railway, Waterloo, Iowa.

A. Swartz, Vice-President, Toledo & Western Railway, Sylvania, Ohio.

W. D. Warren, Maintenance Engineer, New York, New Haven & Hartford Railroad, Lines East, Boston, Mass.

K. G. Williams, Assistant Engineer, Chicago, Rock Island & Pacific Railway, Memphis, Tenn.

COMMITTEE X.

SIGNALS AND INTERLOCKING.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on the problem of signaling single-track roads with reference to the effect of signaling and proper location of passing sidings on the capacity of the line.

3. Report on specifications adopted by the Railway Signal Association, which, in the judgment of the Committee, warrant consideration, conferring with Committee on Track on any appliances affecting track.

4. Report on the desirability of having an overlap in automatic signaling; if so, is it best to have two stop indications between trains or two caution indications instead, or the latter in special cases only, such as down-grade tracks?

5. Report on the various methods of giving signal indications other than by means of the semaphore (this includes the light signal for day and night indications).

6. Report on the feasibility of separating into distinct types of their own (a) the signals for train operation, and (b) the marker of signs which indicate the location or position, or both, of information signs and switch signals for conveying information to trainmen.

   (a) The semaphore is now almost universally used for governing train operation, therefore

   (b) Design suitable day and night (if necessary) markers or signs for switch signals, derail switches, stop posts, slow posts, resume speed posts, water-station and track-pan markers, highway crossing signals, etc., conferring with Committee on Signs, Fences and Crossings.

7. Report on requisites of signal locations for interlocking and block signals.

8. Report on automatic train control.

9. Report on the comparative merits in various locations of alternating current and direct current for operation of automatic signals.

10. Report on applications of aspect for instructions to trains to take siding at a non-interlocked switch.

PERSONNEL.

J. A. Peabody (*Chairman*), Signal Engineer, Chicago & Northwestern Railway, Chicago, Ill.

W. J. Eck (*Vice-Chairman*), Signal and Electrical Engineer, Southern Railway, Washington, D. C.

Azel Ames, Consulting Engineer, New York, N. Y.

C. C. Anthony, Los Altos, Cal.

H. S. Balliet, Assistant Terminal Manager, Grand Central Terminal, and Signal Engineer, Electric Division, New York Central Railroad, East of Buffalo, N. Y.

A. M. Burt, Chief Engineer Maintenance of Way, Northern Pacific Railway, St. Paul, Minn.

C. A. Christofferson, Signal Engineer, Northern Pacific Railway, St. Paul, Minn.

C. E. Denney, Special Engineer to the President, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

F. L. Dodgson, Consulting Engineer, General Railway Signal Company, Rochester, N. Y.
C. A. Dunham, Signal Engineer, Great Northern Railway, St. Paul, Minn.
W. H. Elliott, Signal Engineer, New York Central Railroad, East of Buffalo, Albany, N. Y.
G. E. Ellis, Signal Engineer, Division of Safety, Interstate Commerce Commission, Washington, D. C.
M. H. Hovey, Consulting Engineer, Madison, Wis.
J. G. M. Leisenring, Signal Engineer, Illinois Traction System, Springfield, Ill.
H. K. Lowry, Signal Engineer, Chicago, Rock Island & Pacific Railway, Chicago, Ill.
J. C. Mock, Signal-Electrical Engineer, Michigan Central Railroad, Detroit, Mich.
F. P. Patenall, Signal Engineer, Baltimore & Ohio Railroad, Baltimore, Md.
A. H. Rudd, Signal Engineer, Pennsylvania Railroad, Philadelphia, Pa.
W. B. Scott, President, Southern Pacific Lines in Louisiana and Texas, Houston, Texas.
A. G. Shaver, Consulting Signal and Electrical Engineer, Chicago, Ill.
Thos. S. Stevens, Signal Engineer, Atchison, Topeka & Santa Fe Railway System, Topeka, Kansas.
W. M. Vandersluis, Signal Engineer, Illinois Central Railroad, Chicago, Ill.
B. Wheelwright, Acting Signal Engineer, Grand Trunk Railway, Montreal, Canada.

COMMITTEE XI.

RECORDS AND ACCOUNTS.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on the use of small forms on cardboard or other suitable material for use of fieldmen in making daily reports, to the end that supervision may be facilitated and efficiency encouraged.

3. Report on feasible and useful sub-divisions of the Interstate Commerce Commission "Classification of Investment in Road and Equipment" and "Classification of Operating Expenses" of steam roads.

4. Report on various methods of reproducing maps and profiles on tracing linen for permanent records.

5. Make a comprehensive study of the problem of recording and reporting the cost of additions and betterments.

6. Submit specifications for maps and profiles, coördinating them with previous work of the Association.

7. Report on valuation forms now in use and recommend forms for both field and office use.

8. Report on cost keeping methods and statistical records.

9. Report on a systematic arrangement for final plans in connection with estimates.

10. Report on the allocation of maintenance of way expense to passenger and freight service.

11. Report on additional definitions.

12. Report the following forms:

For Maintenance of Way and Structures:
- (a) Form for monthly report of Track Tools;
- (b) Form for monthly report of Roadway Machines;
- (c) Form for final report of materials used in Tracks.

For Construction:
- (a) Form for monthly estimates of work done by contractors;
- (b) Form for Track-Laying Reports;
- (c) Form for Track-Ballasting Reports;
- (d) Form for Keeping Material Account;
- (e) Form for Keeping Itemized Cost Record;
- (f) Form for Final Detailed Report and Record.

For Records:
- (a) Form for Building Record;
- (b) Form for Water Service Record;
- (c) Form for Fuel Station Record;
- (d) Form for Shop Machinery and Tool Record.

PERSONNEL.

W. A. Christian (*Chairman*), Senior Civil Engineer, Division of Valuation, Interstate Commerce Commission, Chicago, Ill.

M. C. Byers (*Vice-Chairman*), Assistant to President, Western Maryland Railway, Baltimore, Md.

F. L. Beal, Chief Engineer, Louisiana & Arkansas Railway, Stamps, Ark.

Lester Bernstein, Supervisor of Traffic Statistics, Baltimore & Ohio Railroad, Baltimore, Md.

H. Bortin, Cost Engineer, Valuation Department, Central Railroad of New Jersey, New York City.

W. S. Danes, Engineer Maintenance of Way, Wabash Railway, Peru, Ind.

J. W. Fox, Valuation Engineer, Central of Georgia Railway, Savannah, Ga.

B. B. Harris, 35 Nassau Street, New York City.

G. D. Hill, Valuation Department, New York Central Railroad, Cleveland, Ohio.

G. T. Kuntz, Assistant Engineer, Union Pacific Railroad, Wahoe, Neb.

Henry Lehn, Maintenance of Way Accountant, New York Central Railroad, East of Buffalo, New York City.

J H. Milburn, Chief Draftsman, Baltimore & Ohio Railroad, Baltimore, Md.

J. C. Patterson, Office Engineer, Erie Railroad, New York, N. Y.

J. H. Reinholdt, Chief Engineer, Minneapolis & St. Louis Railroad, Minneapolis, Minn.

R. C. Sattley, Valuation Engineer, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

Huntington Smith, Division Engineer, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

H. M. Stout, Record Engineer, Northern Pacific Railway, St. Paul, Minn.

W. D. Wiggins, Valuation Engineer, Pennsylvania Lines West of Pittsburgh, Pittsburgh, Pa.

COMMITTEE XII.

RULES AND ORGANIZATION.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Prepare a "Manual of Instructions for the Guidance of Engineering Field Parties."
3. Continue the study of the Science of Organization.
4. Prepare a "Manual of Rules for the Guidance of Employés of the Maintenance of Way Department."

PERSONNEL.

Jos. Mullen (*Chairman*), Special Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, Cincinnati, Ohio.

F. D. Anthony (*Vice-Chairman*), Construction Engineer, Delaware & Hudson Company, Albany, N. Y.

O. F. Barnes, Division Engineer, Erie Railroad, Jersey City, N. J.

W. C. Barrett, Division Engineer, Lehigh Valley Railroad, Sayre, Pa.

L. L. Beall, Chief Engineer, Atlanta, Birmingham & Atlantic Railroad, Atlanta, Ga.

H. L. Browne, Masonry Inspector, Chicago, Rock Island & Pacific Railway, Des Moines, Iowa.

J. B. Carothers, Receiver, Cincinnati, Findlay & Fort Wayne Railway, Findlay, Ohio.

S. E. Coombs, Special Engineer, New York Central Railroad, East of Buffalo, New York City.

E. J. Correll, Superintendent, Cincinnati, Hamilton & Dayton Railway, Dayton, Ohio.

C. Dougherty, Chief Engineer, Southern Railway, Western Lines, Cincinnati, Ohio.

H. H. Edgerton, Assistant Engineer, Chicago Great Western Railroad, Chicago, Ill.

W. H. Finley, Chief Engineer, Chicago & Northwestern Railway, Chicago, Ill.

B. Herman, Chief Engineer Maintenance of Way and Structures, Southern Railway, Charlotte, N. C.
A. J. Himes, Valuation Engineer, New York, Chicago & St. Louis Railway, Cleveland, Ohio.
F. D. Lakin, Division Engineer, Erie Railroad, Huntington, Ind.
B. M. McDonald, Division Engineer, New York Central Railroad, Buffalo, N. Y.
E. T. Reisler, Civil Engineer, Quakertown, Bucks County, Pa.
W. H. Rupp, Valuation Department, Grand Trunk Railway, Montreal, Canada.
P. T. Simons, 708 Willard Building, Washington, D. C.
R. E. Warden, Assistant Engineer, Missouri Pacific Railroad, Little Rock, Ark.

COMMITTEE XIII.

WATER SERVICE.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Continue the study of methods for complying with Federal regulations in regard to purity of drinking water supplied to trains.

3. Make final report on design of impounding reservoirs, and the conditions under which they are economical.

4. Make final report on relative merits of continuous and intermittent water softeners.

5. Make final report on rules or examination questions for care of boilers in pumping stations.

6. Report on organization for railway water service department.

7. Report on definitions of terms used in railway water service.

8. Report on suitable types of water meters for use in railway water service, methods followed in testing and reading meters and checking the consumption of city water.

PERSONNEL.

A. F. Dorley (*Chairman*), Engineer Maintenance of Way, Missouri Pacific Railroad, St. Louis, Mo.
J. L. Campbell (*Vice-Chairman*), Engineer Maintenance of Way, El Paso & Southwestern System, El Paso, Texas.
J. T. Andrews, Assistant Engineer, Baltimore & Ohio Railroad, Baltimore, Md.
C. A. Ashbaugh, Division Engineer, Gulf, Colorado & Santa Fe Railway, Cleburne, Texas.
R. C. Bardwell, Assistant Engineer, Missouri Pacific Railroad, St. Louis, Mo.
F. T. Beckett, Engineer Maintenance of Way, Chicago, Rock Island & Pacific Railway, El Reno, Okla.
E. H. Brown, Supervisor Bridges and Buildings, Northern Pacific Railway, Minneapolis, Minn.

C. Bucholtz, Assistant Superintendent, Erie Railroad, Youngstown, Ohio.
C. C. Cook, District Engineer, Baltimore & Ohio Railroad, Wheeling, W. Va.
R. H. Gaines, Division Engineer, Kansas City Southern Railway, Texarkana, Texas.
E. M. Grime, Supervisor Bridges and Buildings, Northern Pacific Railway, Dilworth, Minn.
W. C. Harvey, First Assistant Engineer, Chicago Great Western Railroad, Chicago, Ill.
C. R. Knowles, Superintendent Water Service, Illinois Central Railroad, Chicago, Ill.
E. L. Lane, Engineer Maintenance of Way, Baltimore & Ohio Railroad, Western Lines, Cincinnati, Ohio.
J. D. Mathews, Division Engineer, Southern Pacific Company, Tucson, Ariz.
W. A. Murray, Division Engineer, New York Central Railroad, Jersey Shore, Pa.
E. H. Olson, Office Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kansas.
W. A. Parker, Chief Engineer, St. Joseph & Grand Island Railway, St. Joseph, Mo.
H. N. Rodenbaugh, Principal Assistant Engineer, Southern Railway, Washington, D. C.
R. W. Willis, District Engineer, Chicago, Burlington & Quincy Railroad, Chicago, Ill.

COMMITTEE XIV.

YARDS AND TERMINALS.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Report on handling of freight in double-deck freight houses and cost of operation. Also report on handling of freight by mechanical means.
3. Continue study of typical situation plans of passenger stations and methods of their operation.
4. Report on classification yards.

PERSONNEL.

E. B. Temple (*Chairman*), Assistant Chief Engineer, Pennsylvania Railroad, Philadelphia, Pa.
B. H. Mann (*Vice-Chairman*), Signal Engineer, Missouri Pacific Railroad, St. Louis, Mo.
W. G. Arn, Assistant Engineer Maintenance of Way, Illinois Central Railroad, Chicago, Ill.

H. BALDWIN, Assistant Chief Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, Cincinnati, Ohio.

MILES BRONSON, Terminal Manager, Grand Central Terminal, New York Central Railroad, New York City.

G. H. BURGESS, Chairman, Valuation Committee, Delaware & Hudson Company, Albany, N. Y.

A. E. CLIFT, General Superintendent, Illinois Central Railroad, Chicago, Ill.

L. G. CURTIS, District Engineer, Baltimore & Ohio Chicago Terminal Railroad, Chicago, Ill.

H. T. DOUGLAS, JR., Chief Engineer, Chicago & Alton Railroad, Chicago, Ill.

A. C. EVERHAM, Terminal Engineer, Union Pacific Railroad, Kansas City, Mo.

E. M. HASTINGS, Resident Engineer, Richmond. Fredericksburg & Potomac Railroad, Richmond, Va.

D. B. JOHNSTON, Division Engineer, Pennsylvania Lines, Louisville, Ky.

H. A. LANE, Chief Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

F. E. LAMPHERE, Assistant Engineer, Baltimore & Ohio Chicago Terminal Railroad, Chicago, Ill.

A. MONTZHEIMER, Chief Engineer, Elgin, Joliet & Eastern Railway, Joliet, Ill.

H. J. PFEIFER, Engineer Maintenance of Way, Terminal Railroad Association, St. Louis, Mo.

S. S. ROBERTS, Consulting Engineer, Chicago, Ill.

C. H. SPENCER, District Engineer, Division of Valuation, Interstate Commerce Commission, Washington, D. C.

D. F. STEVENS, Superintendent, Baltimore. & Ohio Railroad, Newark, O.

E. E. R. TRATMAN, 202 Ellis Avenue, Wheaton, Ill.

E. P. WEATHERLY, Kansas City, Mo.

W. L. WEBB, District Engineer, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill.

A. J. WHARF, Chief Engineer, Peoria & Pekin Union Railway, Peoria, Ill.

J. G. WISHART, Office Engineer, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

COMMITTEE XV.

IRON AND STEEL STRUCTURES.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Report on methods of protection of iron and steel structures against corrosion.
3. Report on the relative economy of various types of movable bridges.
4. Report on secondary stresses and impact.

5. Report on column tests.

6. Report on design, length and operation of turntables.

7. Report the present practice in construction of ballast-floor bridges and methods in use for waterproofing.

PERSONNEL.

O. E. Selby (*Chairman*), Principal Assistant Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, Cincinnati, Ohio.
F. E. Turneaure (*Vice-Chairman*), Dean, College of Engineering, University of Wisconsin, Madison, Wis.
J. A. Bohland, Bridge Engineer, Great Northern Railway, St. Paul, Minn.
W. S. Bouton, Engineer Bridges, Baltimore & Ohio Railroad, Baltimore, Md.
A. W. Carpenter, Assistant Valuation Engineer, New York Central Railroad, East of Buffalo, New York City.
Charles Chandler, Assistant Bridge Engineer, Illinois Central Railroad, Chicago, Ill.
C. L. Crandall, Professor Railway Engineering, Cornell University, Ithaca, N. Y.
J. E. Crawford, Chief Engineer, Norfolk & Western Railway, Roanoke, Va.
F. O. Dufour, 147 Milk Street, Boston, Mass.
W. R. Edwards, Senior Structural Engineer, Division of Valuation, Interstate Commerce Commission, Washington, D. C.
A. Chas. Irwin, Engineering Department, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill.
J. M. Johnson, Consulting Engineer, Illinois Central Railroad, Louisville, Ky.
B. R. Leffler, Bridge Engineer, New York Central Railroad, West of Buffalo, Cleveland, Ohio.
Crosby Miller, Bridge Engineer, Chesapeake & Ohio Railway, Richmond, Va.
W. H. Moore, Engineer of Structures, New York, New Haven & Hartford Railroad, New Haven, Conn.
P. B. Motley, Engineer of Bridges, Canadian Pacific Railway, Montreal, Canada.
C. D. Purdon, Chief Engineer, St. Louis Southwestern Railway, St. Louis, Mo.
Albert Reichmann, Division Engineer, American Bridge Company, Chicago, Ill.
J. W. Reid, Bridge Engineer, Chicago & Alton Railroad, Chicago, Ill.
A. F. Robinson, Bridge Engineer, Atchison, Topeka & Santa Fe Railway System, Chicago, Ill.
H. B. Seaman, Consulting Engineer, New York City.
C. E. Smith, Consulting Engineer, St. Louis, Mo.

I. F. Stern, Consulting Engineer, Chicago, Ill.

H. B. Stuart, Structural Engineer, Grand Trunk Railway, Montreal, Canada.

G. E. Tebbetts, Bridge Engineer, Kansas City Terminal Railway, Kansas City, Mo.

L. F. Van Hagan, Assistant Professor, University of Wisconsin, Madison, Wis.

J. A. L. Waddell, Consulting Engineer, Kansas City, Mo.

H. T. Welty, Engineer of Structures, New York Central Railroad, New York, N. Y.

COMMITTEE XVI.

ECONOMICS OF RAILWAY LOCATION.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, taking into special consideration a revision of the conclusions in Vol. 16, pages 104 to 109.

2. Report on the resistance of trains running between 35 and 75 miles per hour.

3. (a) Report on the effect of curvature on cost of maintenance of way.

(b) Report on the effect of curvature on maintenance of equipment.

4. Report on the effect of train resistance on the amount of fuel consumed.

5. Report on the entire question of economics of location as affected by the introduction of electric locomotives.

PERSONNEL.

R. N. Begien (*Chairman—Director*), General Manager, Baltimore & Ohio Railroad, Eastern Lines, Baltimore, Md.

C. P. Howard (*Vice-Chairman*), Senior Civil Engineer, Interstate Commerce Commission, Chicago, Ill. (Eight-Hour Commission, Washington, D. C.).

F. H. Alfred, President and General Manager, Pere Marquette Railroad, Detroit, Mich.

A. S. Baldwin (*Past-President*), Chief Engineer, Illinois Central Railroad, Chicago, Ill.

Willard Beahan, First Assistant Engineer, New York Central Railroad, West of Buffalo, Cleveland, Ohio.

E. J. Beugler, Consulting Engineer, Westinghouse, Church, Kerr & Co., New York City.

Ralph Budd, Assistant to President, Great Northern Railway, St. Paul, Minn.

C. L. Crandall, Professor of Railway Engineering, Cornell University, Ithaca, N. Y.

W. J. Cunningham, President's Assistant, Boston & Maine Railroad, Boston, Mass.

C. F. W. **Felt** (*Director*), Chief Engineer, Atchison, Topeka & Santa Fe Railway System, Chicago, Ill.
R. D. **Garner**, Engineer Construction, Southern New England Railroad, Providence, R. I.
A. S. **Going**, Engineer of Construction, Grand Trunk Railway, Montreal, Canada.
A. J. **Himes**, Valuation Engineer, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.
H. C. **Ives**, Professor of Railroad Engineering, Worcester Polytechnic Institute, Worcester, Mass.
W. A. **James**, Engineer of Construction, Canadian Pacific Railway, Winnipeg, Canada.
J. A. **Lahmer**, Assistant Engineer, Missouri Pacific Railroad, S. Louis, Mo.
Fred **Lavis**, Consulting Engineer, 120 Broadway, New York, N. Y.
E. H. **McHenry**, Consulting Engineer, New Haven, Conn.
G. A. **Mountain**, Chief Engineer, Canadian Railway Commission, Ottawa, Canada.
E. C. **Schmidt**, Professor of Railway Engineering, University of Illinois, Urbana, Ill.
A. K. **Shurtleff**, Wilmette, Ill.
C. H. **Splitstone**, Engineer of Construction, Erie Railroad, New York City.
M. F. **Steinberger**, Lighterage Agent, Baltimore & Ohio Railroad, St. George, S. I., N. Y.
A. F. **Stewart**, Chief Engineer, Canadian Northern Railway, Toronto, Canada.
L. L. **Tallyn**, Division Engineer, Delaware, Lackawanna & Western Railroad, Scranton, Pa.
Robt. **Trimble** (*Past-President*), Chief Engineer Maintenance of Way, Pennsylvania Lines West, Pittsburgh, Pa.
W. F. **Tye**, Consulting Engineer, Montreal, Canada.
Walter Loring **Webb**, Stock Exchange Building, Philadelphia, Pa.
H. C. **Williams**, Chief Engineer Construction, Louisville & Nashville Railroad, Louisville, Ky.
M. A. **Zook**, Resident Engineer, Division of Valuation, Interstate Commerce Commission, Washington, D. C.

COMMITTEE XVII.

WOOD PRESERVATION.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, with especial reference to the subject-matter of "Water in Creosote." Special attention is also called to the necessity for revision of the arrangement of the specifications and statements.

2. Report on the compilation of service test records and extend them to include treated timbers in bridges, docks and wharves. Include

also a critical study of the records of service given by the zinc-chloride treatment and state definitely the results which may be obtained from that treatment.

3. Report on the merits of water gas tar as a preservative, taking samples of the preservative from timbers which have been in service, in order to determine its quality.

4. Coöperate with similar committees of other associations with the object of obtaining uniformity in practice and specifications, and report thereon.

PERSONNEL.

Earl Stimson (*Chairman—Second Vice-President*), Engineer Maintenance of Way, Baltimore & Ohio Railroad, Baltimore, Md.

C. M. Taylor (*Vice-Chairman*), Superintendent Treating Plants, Central Railroad of New Jersey and Philadelphia & Reading Railway, Port Reading, N. J.

F. J. Angier, Superintendent Timber Preservation, Baltimore & Ohio Railroad, Baltimore, Md.

F. C. L. Bond (in Military Service).

E. H. Bowser, Superintendent Timber Department, Illinois Central Railroad, Memphis, Tenn.

J. F. Burns, Assistant Engineer Maintenance of Way, Louisville & Nashville Railroad, Louisville, Ky.

W. A. Fisher, 171 Madison Avenue, New York City.

C. F. Ford, Supervisor Tie and Timber Department, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

C. J. Graff, Assistant Engineer, New York Central Railroad, New York City.

R. H. Howard, Chief Engineer Maintenance of Way, Wabash Railway, St. Louis, Mo.

C. H. R. Howe, Division Engineer, Baltimore & Ohio Southwestern Railroad, Chillicothe, Ohio.

J. E. Johnson, Division Engineer, Michigan Central Railroad, St. Thomas, Ont., Can.

George E. Rex, Manager Treating Plants, Atchison, Topeka & Santa Fe Railway, Topeka, Kansas.

H. Stephens, Supervisor of Materials, New York Central Railroad, Cleveland, Ohio.

E. A. Sterling, Consulting Engineer, Chicago, Ill.

Lowry Smith, Superintendent Tie Treating Plants, Northern Pacific Railway, Brainerd, Minn.

O. C. Steinmayer, Supervisor Timber Preservation, St. Louis-San Francisco Railroad, Springfield, Mo.

C. H. Teesdale, in charge of Wood Preservation, Forest Products Laboratory, Madison, Wis.

Dr. Hermann von Schrenk, Consulting Timber Engineer, St. Louis, Mo.

J. H. Waterman, Supervisor of Timber Preservation, Chicago, Burlington & Quincy Railroad, Galesburg, Ill.

COMMITTEE XVIII.

ELECTRICITY.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Keep up to date all statistical data relative to clearances of third-rail and overhead structures.

3. Report on the study of electrolysis and insulation and its effect upon reinforced concrete structures.

4. Report on the study of maintenance organization, and relation to track structures.

5. Report on proper type of overhead catenary construction, with particular reference to the consideration of providing clear vision for signals, coöperating with Committee on Signals and Interlocking.

6. Report on utilization of water power for electrical railway operation, in collaboration with Committee on Conservation of Natural Resources.

7. Report recommended practice for eliminating, as far as practicable, the interference with telephone and telegraph lines caused by the use of propulsion circuits.

8. Report on the interference with telegraph and telephone circuits caused by the use of a direct-current propulsion circuit and methods of eliminating this effect as far as is practicable.

9. Continue coöperation with National Joint Committee on Electrolysis and the National Joint Committee on Overhead and Underground Line Construction.

10. Study and make report on any desirable changes in the National Electrical Safety Code issued by the Bureau of Standards.

PERSONNEL.

E. B. Katte (*Chairman*), Chief Engineer Electric Traction, New York Central Railroad, East of Buffalo, New York City.

A. G. Shaver, (*Vice-Chairman*), Consulting Electrical and Signal Engineer, Chicago, Ill.

A. H. Armstrong, Chairman, Electrification Committee, General Electric Company, Schenectady, N. Y.

H. M. Bassett, Special Assistant Engineer, New York Central Railroad, New York, N. Y.

Z. M. Briggs, Engineer, Pennsylvania Lines West, Pittsburgh, Pa.

R. D. Coombs, Consulting Engineer, New York City.

A. O. Cunningham, Chief Engineer, Wabash Railway, St. Louis, Mo.

Walt Dennis, Principal Assistant Engineer, Wabash Railway, St. Louis, Mo.

R. H. Ford, Engineer Track Elevation, Rock Island Lines, Chicago, Ill.

W. F. Graves, Chief Engineer, Montreal Tramway Company, Montreal, Canada.

George W. Kittredge (*Past-President*), Chief Engineer, New York Central Railroad, East of Buffalo, New York City.

C. E. Lindsay (*Director*), Division Engineer, New York Central Railroad, East of Buffalo, Albany, N. Y.

W. L. Morse, Special Assistant Engineer, New York Central Railroad, New York City.

W. S. Murray, Consulting Engineer, New Haven, Conn.

J. A. Peabody, Signal Engineer, Chicago & Northwestern Railway, Chicago, Ill.

Frank Rhea, Saltburg, Pa.

J. R. Savage, Chief Engineer, Long Island Railroad, Jamaica, N. Y.

Martin Schreiber, Chief Engineer, Public Service Railway, Newark, N. J.

H. U. Wallace, Vice-President, Western Light & Power Company, Boulder, Colo.

COMMITTEE XIX.

CONSERVATION OF NATURAL RESOURCES.

1. Continue the study of tree planting and general reforestation.

2. Collect statistics on extent of use of treated timber and of permanent materials to replace untreated timber and bare steel.

3. Report on the conservation and utilization of water power for railway purposes, conferring with Committee on Electricity.

4. Report on the study of coal, fuel-oil, timber, iron and steel resources.

5. Report on the relation of railways to the different conservation projects, reviewing work that has been done by each company up to the present time, and make recommendations on policies economical for railways to follow.

6. Report on measures for the conservation of human life and energy, in order to promote efficiency.

PERSONNEL.

R. C. Young (*Chairman*), Chief Engineer, Lake Superior & Ishpeming Railway, Marquette, Mich.

S. N. Williams (*Vice-Chairman*), Professor-Emeritus of Civil Engineering (Cornell College, Iowa), Oak Park, Ill.

R. H. Aishton, President, Chicago & Northwestern Railway, Chicago, Ill.

W. K. Barnard, 701 Central Building, Los Angeles, Cal.

C. B. Brown, Chief Engineer, Intercolonial Railway, Moncton, N. B., Canada.

Moses Burpee, Chief Engineer, Bangor & Aroostook Railroad, Houlton, Maine.

C. H. Fisk, Chief Engineer of Construction, St. Louis, Mo.

E. E. King, Professor Railway Engineering, Iowa State College, Ames, Iowa.

C. F. Koppisch, Resident Engineer, Southern New England Railroad, Providence, R. I.

William McNab (*Past-President*), Valuation Engineer, Grand Trunk Railway System, Montreal, Canada.

J. L. Pickles, Chief Engineer, Duluth, Winnipeg & Pacific Railway, West Duluth, Minn.

J. W. Votey, Dean, College of Engineering, University of Vermont, Burlington, Vt.

W. C. Willard, 408 Chittenden Avenue, Columbus, Ohio.

COMMITTEE XX.

UNIFORM GENERAL CONTRACT FORMS.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on forms of agreements for industry tracks.

3. Report on forms of agreements for interlocking and railway crossings, conferring with Committee on Signals and Interlocking, including the rights and obligations of the interested companies.

4. Report on forms of agreement embodying rules governing the construction of under-crossings of railways with electrical conductors, conduits, pipe lines and drains, conferring with Committee on Roadway and Committee on Electricity. (See work done for State Public Utilities Commission of Illinois.)

5. Report on form of lease agreement for industrial site.

PERSONNEL.

E. H. Lee (*Chairman*), Vice-President and Chief Engineer, Chicago & Western Indiana Railway, Chicago, Ill.

C. A. Wilson (*Vice-Chairman*), Consulting Engineer, Cincinnati, Ohio.

C. Frank Allen, West Roxbury, Mass.

S. D. Brady, Chief Engineer, Little Kanawha Lines, Fairmont, W. Va.

O. P. Chamberlain, Chief Engineer, Chicago & Illinois Western Railroad, Chicago, Ill.

John P. Congdon, Consulting Engineer, Boise, Idaho.

Thos. Earle, Vice-President, Bethlehem Steel Bridge Corporation, South Bethlehem, Pa.

W. D. Faucette, Chief Engineer, Seaboard Air Line, Norfolk, Va.

G. E. Gifford, Secretary, Bridge Builders' Society, New York City.

J. C. Irwin, Assistant Engineer Valuation, Boston & Albany Railroad, Boston, Mass.

R. G. Kenly, General Manager, Minneapolis & St. Louis Railroad, Minneapolis, Minn.

A. S. Kent, Chief Engineer, Monon Railroad, Chicago, Ill.

C. J. Parker, Principal Assistant Engineer, New York Central Railroad, New York City.

COMMITTEE XXI.

ECONOMICS OF RAILWAY OPERATION.

1. Study the relations between railway operation and the location, construction and maintenance of railways, and report on the possible scope and field of action which should be assigned to the Committee on Economics of Railway Operation, and make such progress reports as are possible, in the order of relative importance.

PERSONNEL.

F. W. Green (*Chairman*), Assistant to Vice-President, St. Louis Southwestern Railway, St. Louis, Mo.

V. K. Hendricks (*Vice-Chairman*), Assistant Chief Engineer, St. Louis-San Francisco Railway, St. Louis, Mo.

G. D. Brooke, Superintendent, Baltimore & Ohio Railroad, Cumberland, Md.

Ralph Budd, Assistant to President, Great Northern Railway, St. Paul, Minn.

Maurice Coburn, Principal Assistant Engineer, Pennsylvania Lines, St. Louis, Mo.

C. E. Denney, Special Engineer to the President, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

J. M. Egan, Superintendent, Illinois Central Railroad, Fulton, Ky.

L. C. Fritch (*Past-President*), General Manager, Seaboard Air Line Railway, Norfolk, Va.

U. E. Gillen, General Superintendent, Grand Trunk Railway, Chicago, Ill.

C. M. Himmelberger, Assistant Trainmaster, Central Railroad of New Jersey, Jersey City, N. J.

M. V. Hynes, General Superintendent, Cincinnati, Indianapolis & Western Railroad, Indianapolis, Ind.

W. J. Jenks, General Superintendent, Norfolk & Western Railway, Bluefield, W. Va.

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Mott Sawyer, Superintendent, Chicago, Milwaukee & St. Paul Railway, Mason City, Iowa.

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G. S. Waid, Vice-President and General Manager, Sunset Central Lines, Houston, Texas.

C. C. Williams, Professor of Railway Engineering, University of Kansas, Lawrence, Kansas.

COMMITTEE XXII.

ECONOMICS OF RAILWAY LABOR.

1. Study and report on the Economics of Railway Labor.

PERSONNEL.

E. R. Lewis (*Chairman*), Assistant to General Manager, Duluth, South Shore & Atlantic Railroad, Duluth, Minn.

C. H. Stein (*Vice-Chairman*), Superintendent, Central Railroad of New Jersey, Jersey City, N. J.

W. J. Backes, Engineer Maintenance of Way, New York, New Haven & Hartford Railroad, New Haven, Conn.

R. A. Baldwin, Engineer Maintenance of Way, Canadian Northern Railway, Toronto, Ont., Can.

J. Q. Barlow, Assistant Chief Engineer, Southern Pacific Company, San Francisco, Cal.

A. F. Blaess, Engineer Maintenance of Way, Illinois Central Railroad, Chicago, Ill.

W. M. Camp, Editor, Railway Review, Chicago, Ill.

H. M. Church, Division Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

W. R. Dawson, Assistant to General Manager, Norfolk & Western Railway, Roanoke, Va.

R. C. Falconer, Assistant Chief Engineer, Erie Railroad, New York, N. Y.

R. H. Ford, Engineer Track Elevation, Chicago, Rock Island & Pacific Railway, Chicago, Ill.
W. R. Hillary, Supervising Engineer Pennsylvania Lines, Toledo, Ohio.
E. T. Howson, Engineering Editor, Railway Age Gazette, Chicago, Ill.
C. B. Hoyt, Superintendent of Track, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.
C. M. James, Construction Engineer, Atlantic Coast Line, Wilmington, N. C.
W. A. James, Construction Engineer, Canadian Pacific Railway, Winnipeg, Man., Canada.
A. C. Mackenzie, Engineer Maintenance of Way, Canadian Pacific Railway, Montreal, Canada.
J. C. Nelson, Engineer Maintenance of Way, Seaboard Air Line, Norfolk, Va.
C. A. Paquette, Chief Engineer, Cleveland, Cincinnati, Chicago & St. St. Louis Railway, Cincinnati, Ohio.
J. W. Pfau, Construction Engineer, New York Central Railroad, New York, N. Y.
H. R. Safford (*Director*), Chief Engineer, Grand Trunk Railway System, Montreal, Canada.
H. J. Slifer, Consulting Engineer, Chicago, Ill.

SPECIAL COMMITTEE.

GRADING OF LUMBER.

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on classifications and grading rules for all lumber and timber used in the Construction and Maintenance of Way Departments of railways.

(In connection with the study of lumber and timber, this subject seems to be logically the first which should be undertaken and completed. The lumber and timbers which have already been studied by the Committee are: Cypress lumber and shingles, Douglas fir, including structural timber and building materials, and Southern yellow pine, including bridge timber, heart grade, building lumber, and grading rules for hemlock lumber.)

3. Report on specifications for construction timbers and building lumber.

(Having determined upon the classification and grading rules, the specifications based on these rules should follow. The Committee has already reported on oak timbers, Southern yellow pine bridge and trestle timbers, Douglas fir, and Western hemlock bridge and trestle timbers and piles.)

4. From studies 2 and 3, draw up in unified form a set of specifications for construction timbers and building lumber for use on rail-

ways, showing each kind and quality of lumber or timber which is suitable for each of the different classes of work on a railway.

5. Report on specifications for timber which is to be treated with a preservative substance, coöperating with the Committee on Wood Preservation and with Committee on Wooden Bridges and Trestles.

Note:—In connection with all of this work, keep in coöperation with other scientific societies and bureaus and schools of research and investigation, such as the American Society for Testing Materials, the United States Bureau of Standards and Forestry, College Laboratories, etc.

PERSONNEL.

Dr. Hermann von Schrenk (*Chairman*), Consulting Timber Engineer, St. Louis, Mo.

B. A. Wood (*Vice-Chairman*), Chief Engineer, Mobile & Ohio Railroad, Mobile, Ala.

F. C. Baluss, Engineer Bridges and Buildings, Duluth, Missabe & Northern Railway, Duluth, Minn.

W. McC. Bond, Superintendent Construction, Winchester & Virginia Railroad, Winchester, Va.

W. T. Eaton, Chief Engineer, St. Louis Southwestern Railway, Tyler, Texas.

D. Fairchild, Supervisor Bridges and Buildings, Northern Pacific Railway, St. Paul, Minn.

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1022. E. L. Ingram.
1023. Frank Taylor.
1024. S. B. Clement.
1026. J. H. Roach.
1027. J. W. Porter.
1028. W. K. Walker.
1029. H. E. Billman.
1030. Sherman Smith.
1033. W. G. Arn.
1034. H. L. Ripley.
1035. W. M. Mitchell.
1036. W. F. Strouse.
1037. T. W. Fatherson.
1038. Herman Rettinghouse.
1039. J. A. Bohland.
1040. R. C. White.
1041. C. W. Richey.

1042. D. R. Collin.
1044. O. F. Barnes.
1045. Charles Chandler.
1046. I. L. Simmons.
1047. Arthur Crumpton.
1048. D. W. Richards.
1049. G. E. Boyd.
1050. C. N. Monsarrat.
1051. W. L. Rohbock.
1052. J. L. Crider.
1054. Carl Bucholtz.
1055. A. L. Grandy.
1056. G. N. Toops.
1057. G. J. Graves.
1058. F. J. Parrish.
1059. S. B. Rice.
1060. Charles Silliman.
1062. W. A. Christian.
1064. Kenneth Hanger.
1065. M. J. Connerton.
1066. Henry Stephens.
1067. H. W. Brown.
1069. W. J. Towne.
1070. J. E. McNeil.
1071. Raffe Emerson.
1072. E. B. Temple.
1073. H. H. Brewer.
1074. Abraham Bruner.
1075. E. T. Reisler.
1076. J. M. R. Fairbairn.
1078. J. E. Barrett.
1079. H. L. Gordon.
1080. C. W. Huntington.
1081. C. C. Albright.
1082. W. S. Gibson.
1083. W. S. Murray.
1084. W. L. Park.
1085. F. J. Angier.
1086. A. T. Tomlinson.
1087. W. A. Hammel.
1088. E. B. Taylor, Jr.
1089. H. G. Hetzler.
1090. L. C. Lawton.
1092. J. G. M. Leisenring.
1094. Chas. E. Thomas.
1095. W. A. Spell.
1096. George Gibbs.
1097. H. E. Boardman.
1098. Clarence Hoard.
1099. D. W. Thrower.
1101. C. L. Carpenter.
1102. R. J. Arey.
1103. J. H. Reinholdt.
1104. E. B. Katte.
1105. L. C. Hartley.
1106. J. A. Gordon.
1107. G. L. Mattice.
1108. Willson Sprague.
1109. R. H. Rockwood.
1110. M. A. Zook.
1111. George E. Rex.
1112. J. W. Linnbaum.
1113. R. J. Lockwood.
1114. F. T. Beckett.
1115. S. J. Woodhouse.
1116. A. M. Acheson.
1117. J. W. Moore.
1118. C. W. Power.
1119. R. S. McCormick.
1123. N. E. Baker.
1124. E. M. Rosher.
1125. Walter Charnley.
1130. A. H. Stone.
1131. E. H. Shipman.
1132. A. O. Ridgway.
1133. Hans Berents.
1134. G. E. Tebbetts.
1137. W. H. Norris.
1138. H. T. Sympson.
1139. Thos. Z. Krumm.
1142. D. A. Wallace.
1143. J. A. Stocker.
1144. A. C. Prime.
1145. Louis Yager.
1146. C. A. Redinger.
1147. L. F. Van Hagan.
1148. G. W. Hegel.
1149. J. V. Dillabough.
1151. F. E. Lamphere.
1152. John Carmichael.
1153. B. O. Johnson.
1154. Frank Birdsall.
1155. H. Hatcher.
1156. Joseph N. DeStein.
1157. G. T. Warren.
1158. G. W. Harris.
1159. Dennison Fairchild.
1162. E. A. Hadley.
1163. Otto Gersbach.
1164. Edward Gray, Jr.
1165. E. F. Robinson.
1167. R. T. Taylor.
1168. G. H. Harris.
1169. J. R. Savage.
1170. H. T. Carleton.
1171. J. H. Prior.
1172. C. M. Taylor.
1174. J. V. Neubert.
1175. J. B. Carothers.
1176. R. P. Black.
1177. D. L. Sommerville.
1179. H. A. Lloyd.
1180. J. C. Patterson.
1181. A. G. Shaver.
1183. L. D. Harper.
1184. W. H. Vance.
1185. A. T. Hawk.
1186. W. C. Willard.

1188. C. J. Coon.
1189. A. M. Burt.
1190. A. F. Trimble.
1191. J. E. Crawford.
1192. W. S. Danes.
1193. W. L. Webb.
1194. W. F. Purdy.
1196. F. O. Dufour.
1197. R. B. Abbott.
1198. F. D. Batchellor.
1200. A. D. Case.
1201. W. T. Eaton.
1202. T. I. Ellis.
1203. W. H. Finley.
1204. G. Flora.
1205. G. H. Justice.
1206. E. L. Markham.
1207. J. H. Nuelle.
1208. C. P. Ross.
1210. T. G. Townsend.
1211. W. R. Edwards.
1212. E. A. Frink.
1213. G. P. Johnson.
1214. G. P. Palmer.
1216. J. J. Yates.
1218. F. S. Hewes.
1219. Frank Merritt.
1220. H. B. Stuart.
1221. C. B. Patterson.
1222. H. L. Browne.
1223. H. F. Hamilton.
1224. C. M. James.
1225. Harold Knight.
1227. John Tordella.
1228. F. C. Gamble.
1229. James J. Taylor.
1231. O. R. Price.
1232. J. H. Gibboney.
1234. R. M. White.
1235. G. H. Gilbert.
1236. G. N. Edmonson.
1237. F. T. Howes.
1238. D. S. McCalman.
1239. A. P. Miller.
1240. B. Herman.
1241. J. B. Allen.
1242. Lee Perkins.
1243. H. G. Laird.
1244. H. Austill.
1246. O. K. Morgan.
1247. W. McC. Bond.
1249. F. S. Darling.
1250. Maro Johnson.
1251. R. A. Rutledge.
1252. W. L. Milner.
1253. J. L. Dobbins.
1254. E. Raymond.
1255. F. N. Crowell.
1256. L. J. F. Hughes.
1257. W. E. Burkhalter.
1258. E. M. Hastings.
1259. H. H. Harsh.
1260. Martin Schreiber.
1261. J. N. Bridgman.
1262. E. E. King.
1264. I. L. Hibbard.
1265. E. E. Ball.
1266. C. W. P. Ramsey.
1267. F. D. Bardwell.
1268. L. L. Sparrow.
1269. K. B. Duncan.
1270. D. P. Beach.
1271. H. A. Gausewitz.
1272. W. W. Smith.
1274. J. W. Reid.
1275. P. J. Watson, Jr.
1276. F. A. Sherwin.
1277. B. T. Wherry.
1278. F. B. Freeman.
1279. A. W. Carpenter.
1280. H. R. Gibson.
1281. Naonobu Tani.
1284. H. C. Ives.
1285. J. C. Ramage.
1286. C. F. Ford.
1287. H. Pederson.
1288. Fred E. Foss.
1289. L. G. Morphy.
1290. W. C. Whitney.
1291. R. J. Parker.
1292. Chas. F. Burrell.
1293. W. C. Harvey.
1294. D. W. Smith.
1295. M. K. Trumbull.
1296. L. E. Haislip.
1297. J. H. Adamson.
1298. J. R. Onderdonk.
1299. F. T. McGinnis.
1300. W. C. Coles.
1301. P. B. Motley.
1303. K. L. Van Auken.
1304. L. E. Ritter.
1305. E. N. Sanderson.
1307. Jas. C. Hallsted.
1310. F. P. Shearwood.
1311. P. L. Wolfel.
1313. E. B. Fulks.
1314. A. L. Johnson.
1316. P. H. Wilson.
1319. G. H. Kimball.
1320. M. A. Smith.
1321. C. L. Hervey.
1322. A. H. Armstrong.
1323. G. H. Richardson.
1324. A. H. Stewart.
1325. W. R. Weidman.
1326. Walter Buehler.
1327. A. Mordecai.

1328.	E. B. Entwistle.
1330.	B. B. Harris.
1333.	G. W. Rathjens.
1334.	L. C. Dilks.
1335.	Thomas Earle.
1336.	F. D. Beal.
1337.	P. S. Hildreth.
1338.	C. A. Mead.
1340.	C. R. Vanneman.
1342.	G. B. Shipley.
1344.	O. W. Swenson.
1346.	A. L. Kammerer.
1349.	F. S. Foote, Jr.
1350.	E. T. Howson.
1352.	E. W. Powell.
1353.	A. R. Bailey.
1355.	K. R. Chestnut.
1356.	O. W. Albee.
1358.	G. L. Wilson.
1359.	A. V. Brown.
1360.	D. F. Jurgensen.
1361.	George E. Gifford.
1362.	C. F. W. Rys.
1363.	Paul E. Mercier.
1364.	John Maher.
1365.	J. L. Vollintine.
1366.	Geo. W. Godlove, Jr.
1367.	A. C. Copland.
1369.	H. N. Rodenbaugh.
1370.	J. G. Seyfried.
1371.	C. E. Newhouse.
1372.	C. W. Galloway.
1373.	W. C. Cathey.
1374.	F. H. Davis.
1375.	H. C. Booz.
1376.	F. P. Turner.
1377.	W. J. Watson.
1378.	B. Henderson.
1380.	J. B. McClain.
1381.	W. B. Knight.
1382.	W. K. Adams.
1383.	T. S. Johnston.
1384.	B. M. McDonald.
1385.	W. W. Wysor.
1386.	J. F. Murray.
1387.	Carl Stradley.
1388.	J. H. Granbery.
1389.	J. A. Davenport.
1390.	O. T. Waring.
1391.	C. F. Losh.
1392.	G. F. Richan.
1393.	B. J. Dalton.
1394.	J. H. Gallivan.
1395.	J. R. Schick.
1396.	D. F. Harvey.
1397.	C. E. Carson.
1398.	A. H. Hogeland.
1400.	H. W. Hudson.
1401.	W. S. Lacher.
1402.	L. B. Allen.
1403	Charles Kaighn.
1404.	L. F. Lonnbladh.
1405.	W. W. Wilson.
1406.	H. E. Riggs.
1407.	C. L. Crabbs.
1408.	T. B. Powell.
1409.	A. C. Mackenzie.
1410.	W. T. Hughes.
1411.	R. G. Glass.
1412.	S. C. Houser.
1413.	H. B. MacFarland.
1414.	C. W. Brown.
1415.	R. V. Glover.
1416.	W. G. Massenburg.
1417.	Mott Sawyer.
1419.	S. L. Wonson.
1420.	P. H. Spear.
1421.	Albert Larsen.
1422.	Geo. L. Norris.
1423.	A. J. Bisbee.
1424.	J. W. Dawson.
1425.	A. B. Ziegweid.
1426.	J. T. Andrews.
1427.	W. H. Gardner, Jr.
1428.	A. F. Comstock.
1429.	P. W. Early.
1430.	H. H. Althouse.
1431.	J. M. Isbell.
1432.	R. D. Garner.
1433.	E. L. Taylor.
1435.	A. L. Sarvey.
1436.	Robt. C. Sattley.
1437.	H. M. Hayward.
1438.	Chas. H. Blackman.
1439.	Murray Sullivan.
1440.	H. H. Trabue.
1441.	C. C. Williams.
1443.	A. A. McCree.
1445.	H. Bortin.
1447.	J. S. McBride.
1448.	C. A. Ashbaugh.
1449.	W. A. Guild.
1450.	B. M. Cheney.
1451.	W. P. Cronican.
1452.	G. F. Eberly.
1454.	E. C. Schmidt.
1455.	R. P. Rockefeller.
1456.	Adam Ritter.
1457.	A. W. Owen.
1458.	George Story, Jr.
1459.	J. H. Richardson.
1460.	C. S. Sheldon.
1461.	E. A. Probst.
1462.	E. W. Oliver.
1464.	H. A. Weaver.
1465.	W. T. Spencer.
1466.	W. Forrest Ogle.
1467.	C. M. Nye.

1468. R. H. Garrett.
1469. R. A. Cummings.
1470. Francis Boardman.
1471. J. G. Reid.
1472. R. W. West.
1473. J. L. Kirby.
1474. T. E. Rust.
1475. W. W. Morrison.
1476. D. J. Kerr.
1478. F. W. Blake.
1479. L. L. Tallyn.
1480. Howard O'Connor.
1481. J. S. Bassett.
1482. J. S. Unger.
1483. H. C. Brown, Jr.
1484. Miles Bronson.
1485. J. A. Hedgcock.
1486. J. C. Holden.
1488. J. W. Pfau.
1489. Samuel Rockwell, Jr.
1490. H. T. Ross.
1491. A. M. Traugott.
1492. W. J. Jenks.
1493. G. D. Snyder.
1494. J. E. Teal.
1495. H. R. Beebe.
1497. J. Vipond Davies.
1498. C. P. Richardson.
1499. T. B. Whitney, Jr.
1500. G. W. Payne.
1501. H. B. Barry.
1502. M. M. Marsh.
1503. D. F. Crawford.
1504. G. K. Cooper.
1506. C. S. Kirkpatrick.
1507. B. C. Martin.
1509. A. W. Gibbs.
1510. L. O. Sloggett.
1512. R. C. Crocker.
1513. R. S. Hubley.
1514. F. W. Pfleging.
1515. C. W. Stark.
1516. J. W. Pearson.
1517. Paul Sterling.
1518. H. H. Groves.
1519. O. H. Ammann.
1521. P. T. Simons.
1522. R. E. Warden.
1524. Chas. L. Ruffin.
1525. A. Bromley Smith.
1526. W. F. Graves.
1527. J. A. Donahey.
1528. Frank L. Guy.
1530. Nelson Caderette.
1531. L. E. Faulkner.
1532. W. O. Galbreath.
1533. H. T. Hazen.
1534. P. L. Hoskins.
1535. R. J. McComb.
1536. W. L. Morse.
1537. C. E. Reeves.
1539. J. L. Pickles.
1540. M. C. Blanchard.
1541. D. W. Cronin.
1542. J. B. Trenholm.
1543. A. R. Hannaford.
1546. E. P. Sisson.
1547. P. D. Fitzpatrick.
1548. G. R. Kent.
1549. Thomas Quigley.
1550. M. E. Steinberger.
1551. B. A. Underwood.
1552. C. L. Whiting.
1553. W. J. Cunningham.
1554. C. A. Hewes.
1555. David McCooe.
1556. G. W. Abbott.
1557. T. T. Irving.
1558. Chas. Forrester.
1559. E. J. Beugler.
1560. K. G. Williams.
1561. H. G. Snyder.
1562. A. S. Lyon.
1563. F. G. Hoskins.
1564. H. A. Cassil.
1565. L. L. Beall.
1566. A. Chas. Irwin.
1567. A. M. Blanchard.
1568. J. D. Koren.
1569. F. B. Marble.
1570. A. J. Wharf.
1571. W. D. Faucette.
1572. John Howe Peyton.
1573. E. P. Laird.
1574. C. M. Larsen.
1576. John M. Weir.
1577. John Evans.
1579. Francis Nugent.
1580. W. D. Warren.
1581. E. G. Hewson.
1583. C. F. Koppisch.
1584. A. M. Van Auken.
1585. Lester Bernstein.
1586. G. H. Friend.
1587. W. P. Kellett.
1588. R. A. Baldwin.
1589. H. A. Phelps.
1590. Geo. A. Mitchell.
1592. W. J. Knolles.
1593. C. E. Norman.
1594. P. B. Tallman.
1595. C. P. Hammond.
1596. W. M. Vandersluis.
1598. H. C. Williams.
1599. H. W. Thornton.
1600. G. H. Dryden.
1601. W. A. Casler.
1602. D. M. Taylor.

1603. W. C. Kegler.
1604. J. J. Richardson.
1605. C. J. Chenworth.
1606. William Jones.
1607. F. H. Ellsworth.
1608. C. A. Daley.
1609. A. T. North.
1610. E. T. Agate.
1612. L. F. McCoy.
1613. M. H. Gold.
1614. W. H. Cookman.
1615. W. S. Murray.
1616. C. S. Heritage.
1619. Richard Brooke.
1620. S. R. Church.
1621. R. F. Hamilton.
1622. H. C. Goodrich.
1623. J. T. Elmore.
1624. E. B. Crane.
1625. E. L. Cousins.
1626. C. G. E. Larsson.
1627. L. B. Shipley.
1628. Clarence Blakeslee.
1630. S. D. Bacon.
1631. C. H. Teesdale.
1632. E. J. Correll.
1633. L. A. Cottingham.
1634. E. A. Harrison.
1635. W. C. Taylor.
1636. F. X. Amoss.
1637. F. A. Jones.
1638. H. E. Astley.
1639. R. P. Davis.
1640. J. H. Wasson.
1641. W. H. Rupp.
1642. E. H. Brown.
1643. C. W. Bulkley.
1644. D. W. Gross.
1645. J. M. Sills.
1646. J. W. Welling.
1649. J. S. Browne.
1650. W. R. Roof.
1651. W. A. Cattell.
1652. C. E. Weaver.
1653. Daniel Coughlin.
1654. H. K. Lowry.
1655. A. C. Shields.
1656. C. M. Himmelberger.
1658. C. L. Ruppert.
1659. F. E. Watson.
1660. R. Elmer Demuth.
1661. E. P. Swartz.
1662. H. P. Greenough.
1663. Crosby Miller.
1664. J. A. McGrew.
1665. H. U. Mudge.
1666. A. C. Bradley.
1668. S. J. Buckalew.
1669. Z. M. Briggs.
1671. E. R. Cary.
1672. W. A. Jones.
1673. H. E. Stansbury.
1674. R. B. Shepard, Jr.
1675. H. A. Palmer.
1676. A. B. Caldwell.
1677. F. W. Alexander.
1678. C. D. MacKintosh.
1679. H. Steenbuch.
1680. J. W. Stewart.
1681. F. Auryansen.
1682. F. C. L. Bond.
1683. C. G. Bryan.
1684. H. W. McLeod.
1685. Lowry Smith.
1686. Noah Johnson.
1687. F. W. Leatherbury.
1688. E. M. Grime.
1689. J. L. Taylor.
1690. W. A. Fisher.
1691. F. J. Challoner.
1692. G. A. Haggander.
1693. T. J. McCarvel.
1694. H. B. Spencer.
1696. E. W. Smith.
1697. Y. Maruyama.
1698. G. R. Barry.
1699. S. P. Brown.
1700. E. S. Draper.
1701. C. R. Knowles.
1702. D. M. McKey.
1703. L. A. Murr.
1704. R. R. Paine.
1705. B. B. Shaw.
1706. E. D. Sloan.
1707. W. R. Dawson.
1708. C. W. Beam.
1709. J. L. Doupe.
1710. J. S. Hestle.
1711. A. L. Mills.
1712. F. J. Reinke.
1713. W. F. Tams.
1714. Chas. A. Hayes.
1715. H. M. Sperry.
1716. F. L. Dodgson.
1717. H. E. Hilts.
1718. Harvey Stanley.
1719. A. F. Colligan.
1720. C. A. Dayton.
1721. A. E. Deal.
1722. G. T. Hand.
1723. L. G. Krause.
1724. W. L. Lozier.
1725. C. W. Simpson.
1727. D. R. Young.
1728. G. Lindenthal.
1729. A. S. Richey.
1730. E. J. Lassiter.
1731. F. L. Beal.

1732. D. B. Cutler.
1733. W. L. Darden.
1734. M. H. Doughty.
1735. T. M. Hutson.
1736. W. M. Kinney.
1737. L. H. Lacy.
1738. R. L. Latham.
1739. J. E. O'Donnell.
1740. L. E. Silcox.
1741. W. L. Brown.
1742. F. W. Cherrington.
1743. F. H. Gross.
1744. C. M. McVay.
1745. S. C. Stafford.
1746. G. S. Waid.
1747. E. E. Adams.
1748. H. B. Titcomb.
1749. J. A. Otto.
1750. J. D. Mathews.
1751. W. R. Hillary.
1753. J. Q. Barlow.
1754. C. A. Wester.
1755. O. Weeks.
1756. S. T. Wagner.
1757. F. S. Schwinn.
1758. R. C. Watkins.
1759. A. P. Williams.
1760. F. R. Ramsey.
1761. D. A. Porter.
1762. A. W. Perrin.
1763. A. T. Mercier.
1764. C. T. Hsia.
1765. R. L. Holmes.
1766. K. E. Hendricks.
1767. A. R. Dewees.
1768. C. T. Delamere.
1769. L. A. Mitchell.
1770. C. R. Morrill.
1771. Z. H. Sikes.
1772. C. M. Staples.
1773. J. F. Whiteside.
1774. E. A. Wood.
1775. W. M. Jaekle.
1776. W. H. Kirkbride.
1777. E. B. Hillegass.
1778. R. Jones.
1779. F. M. Siefer.
1780. F. F. Hanly.
1781. F. D. Lakin.
1782. S. Kurokochi.
1783. J. B. Gaut.
1784. W. P. Kimble.
1785. J. R. Sexton.
1786. C. M. Goodrich.
1787. F. C. Baluss.
1788. R. M. Drake.
1789. E. C. Morrison.
1790. C. W. Baldridge.
1791. W. C. Barnes.
1792. S. L. McClanahan.
1793. E. F. Manson.
1794. J. H. Reagan.
1795. John Archer.
1796. H. S. Blake.
1797. R. H. Boykin.
1798. R. L. Dyke.
1799. C. J. Graff.
1800. F. F. Harrington.
1802. L. V. Manspeaker, Jr.
1803. F. A. Merrill.
1804. G. E. Roehm.
1805. I. H. Schram.
1806. O. H. Sessions.
1807. O. C. Steinmayer.
1808. A. M. Turner.
1809. R. P. Waters.
1810. E. C. Baity.
1811. W. A. Brewer.
1812. C. W. Gennet, Jr.
1813. T. M. Pittman, Jr.
1814. J. A. Roach.
1815. R. L. Schmid.
1816. A. S. Butterworth.
1817. J. R. Taft.
1818. J. W. Walter.
1819. H. J. Moore.
1820. H. A. Hatch.
1821. W. C. Nisbet.
1822. C. S. Heritage.
1823. C. C. Small.
1824. R. E. Woodruff.
1825. V. R. Irvine.
1826. R. V. Reamer.
1827. W. R. Davis.
1828. J. Schofield.
1830. H. A. Dixon.
1831. C. W. Fee.
1832. R. J. Gammie.
1833. U. E. Gillen.
1834. A. T. Hopkins.
1835. G. T. Kuntz.
1836. C. M. Lewis.
1837. D. P. Pace.
1838. R. L. Pearson.
1839. C. D. Perkins.
1840. S. B. Phillips.
1841. J. S. Robinson.
1842. J. S. Ruff.
1843. J. L. Starkie.
1844. L. I. Stone.
1845. T. E. White.
1846. C. F. Yardley.
1847. G. R. Sinnickson.
1848. R. R. Hancock.
1849. B. Wheelwright.
1850. Lewis Mims.
1851. R. G. Wilson.
1852. C. H. Dana.

1853. Springfield Baldwin.
1854. G. F. Hand.
1855. J. F. McNally.
1856. J. B. Strong.
1857. D. F. Stevens.
1858. C. B. Andrews.
1859. W. E. Meilly.
1860. Guy Pinner.
1861. C. C. Westfall.
1862. F. H. McGuigan, Jr.
1863. Joseph H. Waterman.
1864. Harry Slabotsky.
1865. Kikumatsu Hirai.
1866. Oliver Owre.
1867. J. F. Keegan.
1868. R. W. Davis.
1869. W. O. Lord.
1870. W. A. Cowan.
1871. C. E. Merwin.
1872. C. S. Coe.
1873. Walter Sparke.
1874. C. Dillenbeck.
1875. F. C. Shepard.
1876. H. J. Sargent.
1877. R. J. Hammond.
1878. R. M. Miller.
1879. Victor Angerer.
1880. W. F. Jordan.
1881. W. W. Kelly.
1882. J. E. Kissell.
1883. J. W. Votey.
1884. J. E. Fraser.
1885. A. B. Griggs.
1886. W. K. Etter.
1887. R. S. Mitchell.
1888. H. C. Lothholz.
1889. A. E. Owen.
1890. W. C. Baisinger.
1891. F. von Sprecken.
1892. W. F. McDade.
1893. E. E. Worthing.
1894. V. T. Boughton.
1895. E. J. Bayer.
1896. H. W. Oxnard.
1897. F. S. Harvey.
1898. J. G. Teders.
1899. E. H. Barnhart.
1900. W. A. Moncure.
1901. D. A. Riley.
1902. Robert Reimann.
1903. J. V. McNab.
1904. J. M. Davis.
1905. J. C. Nagle.
1906. A. F. Maischaider.
1907. E. W. Grant.
1908. M. H. Cahill.
1909. Theo. Bloecher, Jr.
1910. D. E. Helvern.
1911. N. M. Hench.
1912. P. S. Lewis.
1913. O. V. Parsons.
1914. E. M. Rhodes.
1915. G. W. Snyder.
1916. H. T. Welty.
1917. R. C. Bardwell.
1918. G. C. Tuthill.
1919. W. S. Burnett.
1920. G. W. Corrigan.
1921. J. D. Elder.
1922. E. L. Landorph.
1923. J. A. Nichols, Jr.
1924. W. S. Moore.
1925. T. C. Crea.
1926. W. C. Heidenthal.
1927. Joseph Weidel.
1928. W. M. Ray.
1929. W. K. Walker.
1930. C. M. Buck.
1931. R. C. Howard.
1932. John Hewes, Jr.
1933. James Boyd.
1934. E. B. Skeels.
1935. H. M. Bassett.
1936. G. P. DeWolf.
1937. M. C. Shibley.
1938. G. P. Lang, Jr.
1939. A. C. Spencer.
1940. J. G. Little.
1941. H. H. Edgerton.
1942. F. H. Masters.
1943. R. E. Keough.
1944. J. J. Glass.
1945. F. W. Bailey.
1946. W. J. Gooding.
1947. R. A. Cook.
1948. C. E. Johnston.
1949. J. A. Gillies.
1950. A. H. Freygang.
1951. N. E. Boucher.
1952. A. W. Macpherson.
1953. S. C. Jump.
1954. C. E. Cate.
1955. J. W. Fox.
1956. R. N. Priest.
1957. E. B. Sloan.
1958. A. M. Davidson.
1959. G. B. Farlow.
1960. F. X. Soete.
1961. C. S. Flandreaux.
1962. T. H. Sears.
1963. J. G. Gwyn.
1964. J. W. Dansey.
1965. H. J. Smith.
1966. H. R. Carpenter.
1967. H. H. Swisher.
1968. C. C. Strong.

1969. E. H. Olson.
1970. E. L. Crugar.
1971. S. C. Ondarcho.
1972. G. F. Blackie.
1973. J. R. Fordyce.
1974. W. P. Ball.
1975. S. C. Gebert.
1976. M. K. McQuarrie.
1977. J. P. Nelson.
1978. H. A. Osgood.
1979. W. H. Hulsizer.
1980. Rioye Ono.
1981. Bernard Blum.
1982. C. H. Niemeyer.
1983. T. L. Doyle.

LIST OF MEMBERS.

A

384. **Abbott, F. E.,**
Inspecting Engineer, Lackawanna Steel Company, Buffalo, N. Y.

1556. **Abbott, G. W.,**
Division Engineer, Boston & Albany Railroad, Boston, Mass.

1197. **Abbott, R. B.,**
Superintendent, Philadelphia & Reading Railway, Harrisburg, Pa.

1116. **Acheson, A. M.,**
Superintendent, Missouri, Kansas & Texas Railway, Trinity, Texas.

1747. **Adams, E. E.,**
Consulting Engineer, Union Pacific Railroad, New York City.

1382. **Adams, W. K.,**
Fort Sam Houston, Texas.

1297. **Adamson, J. H.,**
Field Engineer, Baltimore & Ohio Railroad, Meyersdale, Pa.

1610. **Agate, E. T.,**
Pittsford, N. Y.

237. **Aishton, R. H.,**
President, Chicago & Northwestern Railway, Chicago, Ill.

1356. ***Albee, O. W.,**
Constructing and Inspecting Engineer, Detroit, Mich.

1081. **Albright, C. C.,**
Associate Professor Civil Engineering, Purdue University, Lafayette, Ind.

1677. **Alexander, F. W.,**
Division Engineer, Canadian Pacific Railway, Calgary, Alberta, Canada.

164. **Alfred, F. H.,**
President and General Manager, Pere Marquette Railroad, Detroit, Mich.

893. ***Allee, O. P.,**
President, Railway Concrete Supply Company, Kansas City, Kansas.

440. **Allen, Andrews,**
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298. **Allen, C. Frank,**
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1241. **Allen, J. B.,**
Inspecting Engineer, Usulutan, Republic of El Salvador, Central America.

1402. **Allen, L. B.,**
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1430. ***Althouse, H. H.,**
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869. **Ambrose, J. R. W.,**
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688. ***Ames, Azel,**
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1519. **Ammann, O. H.,**
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1636. **Amoss, F. X.,**
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1858. **Andrews, C. B.,**
Chief Engineer, Oahu Railway and Land Company, Honolulu, Hawaii.

843. **Andrews, G. W.,**
Assistant to Engineer Maintenance of Way, Baltimore & Ohio Railroad, Baltimore, Md.

1426. **Andrews, J. T.,**
Assistant Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

394. **Andros, F. W.,**
35 Cedar Street, Taunton, Mass.

1879. ***Angerer, Victor,**
President, Wm. Wharton, Jr., & Company, Easton, Pa.

1085. **Angier, F. J.,**
Superintendent Timber Preservation, Baltimore & Ohio Railroad, Baltimore, Md.

674. **Anthony, C. C.,**
Los Altos, Cal.

55. **Anthony, F. D.,**
Construction Engineer, Delaware & Hudson Company, Albany, N. Y.

1795. **Archer, John,**
Resident Engineer, Norfolk Southern Railroad, Norfolk, Va.

39. **Archer, William,**
Assistant Engineer, Baltimore & Ohio Southwestern Railroad, Cincinnati, Ohio.

1102. ***Arey, R. J.,**
Consulting Engineer, Los Angeles, Cal.

951. **Armour, Robert,**
Masonry Engineer, Grand Trunk Railway System, Montreal, Canada.

1322. ***Armstrong, A. H.,**
Chairman, Electrification Committee, General Electric Company, Schenectady, N. Y.

940. **Armstrong, H. J.,**
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1033. **★Arn, W. G.,**
Assistant Engineer Maintenance of Way, Illinois Central Railroad, Chicago, Ill.

959. **Arthur, G. F.,**
Assistant Engineer, Illinois Central Railroad, Chicago, Ill.

1448. **Ashbaugh, C. A.,**
Division Engineer, Gulf, Colorado & Santa Fe Railway, Cleburne, Texas.

334. **Ashby, E. B.,**
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*Associate. ★In Military Service.

1638. **Astley, H. E.,**
Superintendent Midland Division, New York, New Haven & Hartford Railroad, Boston, Mass.

129. **Atwood, J. A.** (*Director*),
Chief Engineer, Pittsburgh & Lake Erie Railroad, Pittsburgh, Pa.

989. ★**Atwood, W. G.,**
Assistant District Engineer, Division of Valuation, Interstate Commerce Commission, Chattanooga, Tenn.

1681. **Auryansen, F.,**
Bridge Engineer, Long Island Railroad, Jamaica, N. Y.

1244. **Austill, H.,**
Bridge Engineer, Mobile & Ohio Railroad, Mobile, Ala.

B

634. **Bachelder, F. J.,**
Consulting Engineer, Chicago, Ill.

900. **Backes, W. J.,**
Engineer Maintenance of Way, New York, New Haven & Hartford Railroad, New Haven, Conn.

1630. **Bacon, S. D.,**
Division Engineer, Texas & Pacific Railway, Marshall, Texas.

549. **Bagg, F. A.,**
Chief Engineer, Fonda, Johnstown & Gloversville Railroad, Gloversville, N. Y.

1353. **Bailey, A. R.,**
Assistant Professor, University of Michigan, Ann Arbor, Mich.

1945. **Bailey, F. W.,**
Superintendent Maintenance of Way, San Antonio & Aransas Pass Railway, Yoakum, Texas.

1890. **Baisinger, W. C.,**
Assistant Engineer on Construction, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

1810. **Baity, E. C.,**
Assistant Engineer, St. Louis-San Francisco Railroad, Springfield, Mo.

56. **Baker, Horace,**
General Manager, Southern Railway, Western Lines, Cincinnati, Ohio.

1123. **Baker, N. E.,**
Supervisor of Signals, Grand Trunk Railway, Battle Creek, Mich.

1790. **Baldridge, C. W.,**
Assistant Engineer, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

447. **Baldwin, A. S.** (*Past-President*),
Chief Engineer, Illinois Central Railroad, Chicago, Ill.

73. **Baldwin, Hadley,**
Assistant Chief Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, Cincinnati, Ohio.

382. **Baldwin, L. W.,**
Vice-President and General Manager, Central of Georgia Railway, Savannah, Ga.

1588. **Baldwin, Robert A.,**
Assistant Engineer, Canadian Northern Railway, Toronto, Ont., Canada.

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*Associate. ★In Military Service.

1853. **Baldwin, Springfield,**
Valuation Engineer, Trinity & Brazos Valley Railroad, Teague, Texas.

1265. **Ball, E. E.,**
Division Engineer, Atchison, Topeka & Santa Fe Railway, Fresno, Cal.

1974. **Ball, W. P.,**
Assistant Division Engineer, Baltimore & Ohio Southwestern Railroad, Cincinnati, Ohio.

637. **Balliet, H. S.,**
Assistant Terminal Manager and Signal Engineer, Electric Division, New York Central Railroad, East of Buffalo, Grand Central Terminal, New York, N. Y.

1787. **Baluss, F. C.,**
Engineer Bridges and Buildings, Duluth, Missabe & Northern Railway, Duluth, Minn.

1267. **Bardwell, F. D.,**
Special Assistant Engineer, New York Central Railroad, East of Buffalo, New York, N. Y.

1917. **Bardwell, R. C.,**
Assistant Engineer, Missouri Pacific Railroad, St. Louis, Mo.

1753. **Barlow, J. Q.,**
Assistant Chief Engineer, Southern Pacific Company, San Francisco, Cal.

90. **Barnard, R. C.,**
Superintendent, Pennsylvania Lines, Cincinnati, Ohio.

912. ***Barnard, W. K.,**
Consulting Engineer, 1105 Central Building, Los Angeles, Cal.

996. **Barnes, F. A.,**
Assistant Professor of Railroad Engineering, Cornell University, Ithaca, N. Y.

1044. **Barnes, O. F.,**
Division Engineer, Erie Railroad, Jersey City, N. J.

1791. **Barnes, W. C,**
Assistant Consulting Engineer, Southern Pacific Company, New York City.

1899. **Barnhart, E. H.,**
Division Engineer, Baltimore & Ohio Railroad, Wheeling, W. Va.

1078. **Barrett, J. E.,**
Superintendent Track, Bridges and Buildings, Lehigh & Hudson River Railroad, Warwick, N. Y.

737. **Barrett, W. C.,**
Division Engineer, Lehigh Valley Railroad, Sayre, Pa.

1698. **Barry, G. R.,**
Division Engineer, Pennsylvania Lines, Columbus, Ohio.

1501. **Barry, H. B.,**
District Engineer, St. Louis-San Francisco Railroad, Memphis, Tenn.

1935. **Bassett, H. M.,**
Special Assistant Engineer, New York Central Railroad, New York, N. Y.

1481. **Bassett, J. S.,**
Assistant Engineer, Missouri Pacific Railroad, Monroe, La.

1198. **Batchellor, F. D.,**
District Engineer, Baltimore & Ohio Railroad and Cincinnati, Hamilton & Dayton Railway, Cincinnati, Ohio.

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*Associate.

119. **Bates, Onward,**
Consulting Engineer, 332 South Michigan Avenue, Chicago, Ill.

1895. **Bayer, E. J.,**
Assistant Engineer Maintenance of Way, Cleveland, Cincinnati, Chicago & St. Louis Railway, Galion, Ohio.

1270. **Beach, D. P.,**
Division Engineer, Pennsylvania Lines West of Pittsburgh, Indianapolis, Ind.

672. **Beahan, Willard,**
First Assistant Engineer, New York Central Railroad, West of Buffalo, Cleveland, Ohio.

1336. ***Beal, F. D.,**
414 Insurance Exchange Building, San Francisco, Cal.

1731. **Beal, F. L.,**
Chief Engineer, Louisiana & Arkansas Railway, Stamps, Ark.

1565. **Beall, L. L.,**
Chief Engineer, Atlanta, Birmingham & Atlantic Railroad, Atlanta, Ga.

1708. **Beam, C. W.,**
Assistant Engineer, New York Central Railroad, East of Buffalo, Buffalo, N. Y.

1114. **Beckett, F. T.,**
Engineer Maintenance of Way, Chicago, Rock Island & Pacific Railway, El Reno, Okla.

1495. ***Beebe, H. R.,**
Railroad Contractor, Utica, N. Y.

754. **Begien, R. N. (*Director*),**
General Manager, Baltimore & Ohio Railroad, Eastern Lines, Baltimore, Md.

836. **Bell, Gilbert J.,**
Engineer, Western District, Atchison, Topeka & Santa Fe Railway, Newton, Kansas.

239. **Bell, Robert,**
Special Agent, Pennsylvania Railroad, Buffalo, N. Y.

568. **Bentele, Hans,**
Assistant Chief Engineer, National Railways of Mexico, City of Mexico, Mexico.

1133. **Berents, Hans,**
Consulting Engineer, Shanghai, China.

736. **Bergen, W. J.,**
First Assistant to Chief Engineer, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

1585. **Bernstein, Lester,**
Supervisor Traffic Statistics, Baltimore & Ohio Railroad, Baltimore, Md.

179. **Berry, J. B.,**
Consulting Engineer, 1640 Transportation Building, Chicago, Ill.

238. **Besler, W. G.,**
President and General Manager, Central Railroad of New Jersey, 143 Liberty Street, New York, N. Y.

780. **Bettle, F. W.,**
Division Engineer, Texas & Pacific Railway, Big Spring, Texas.

1559. ***Beugler, Edwin J.,**
Consulting Engineer, Westinghouse, Church, Kerr & Company, 37 Wall Street, New York, N. Y.

---

*Associate.

515. **Beye, J. C,**

Locating Engineer, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

1029. **Billman, H. E.,**

General Roadmaster, Missouri Pacific Railroad, St. Louis, Mo.

1154. **Birdsall, Frank L.,**

Superintendent, Minnesota, Dakota & Western Railway, International Falls, Minn.

1423. **Bisbee, A. J.,**

Assistant Engineer, Valuation Department, Chicago, Rock Island & Pacific Railway, Chicago, Ill.

47. **Bisbee, F. M.,**

Chief Engineer, Western Lines, Atchison, Topeka & Santa Fe Railway, Amarillo, Texas.

227. **Bissell, F. E.,**

Senior Civil Engineer, Division of Valuation, Interstate Commerce Commission, Chattanooga, Tenn.

791. ***Bivins, P. A.,**

74 Park Avenue, Passaic Park, N. J.

1009. **Black, G. F.,**

Engineer Maintenance of Way, Maine Central Railroad, Portland, Maine.

1176. **Black, R. P.,**

University Engineer, University of the South, Sewanee, Tenn.

1972. **Blackie, G. F.,**

Assistant Chief Engineer, Nashville, Chattanooga & St. Louis Railway, Nashville, Tenn.

1438. **Blackman, Chas. H.,**

Principal Assistant Engineer, Louisville & Nashville Railroad, Louisville, Ky.

675. **Blaess, A. F.,**

Engineer Maintenance of Way, Illinois Central Railroad, Chicago, Ill.

859. **Blaiklock, M. S.,**

Engineer Maintenance of Way, Grand Trunk Railway System, Montreal, Canada.

1478. **Blake, F. W.,**

General Manager, Tehuantepec National Railway, Rincon Antonio, Oaxaca, Mexico.

1796. **Blake, H. S.,**

Resident Engineer, Norfolk Southern Railroad, Norfolk, Va.

1628. ***Blakeslee, Clarence,**

Treasurer and Consulting Engineer, Branford Steam Railroad, New Haven, Conn.

1567. **Blanchard, Alfred M.,**

Valuation Department, Grand Trunk Railway, Montreal, Canada.

1540. **Blanchard, M. C.,**

Engineer, Eastern District, Atchison, Topeka & Santa Fe Railway, Topeka, Kansas.

865. **Bland, J. C.,**

Engineer of Bridges, Pennsylvania Lines, Pittsburgh, Pa.

1909. **Bloecher, Theo., Jr.,**

Division Engineer, Baltimore & Ohio Railroad, Philadelphia, Pa.

1981. **Blum, Bernard,**

Division Engineer, Northern Pacific Railway, St. Paul, Minn.

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*Associate.

1470. **Boardman, Francis,**
Division Engineer, Electric Division, New York Central Railroad, East of Buffalo, New York, N. Y.

1097. **Boardman, H. E.,**
Assistant Engineer, Valuation Department, New York Central Railroad, New York City.

1039. **Bohland, J. A.,**
Bridge Engineer, Great Northern Railway, St. Paul, Minn.

1682. **★Bond, F. C. L.,**
Division Engineer, Grand Trunk Railway, Montreal, Canada.

1247. **Bond, W. McC.,**
Superintendent Construction, Winchester & Virginia Railroad, Winchester, Va.

128. **Boots, E. W.,**
Assistant Engineer, Pittsburgh & Lake Erie Railroad, Pittsburgh, Pa.

1375. **Booz, H. C.,**
Assistant Chief Engineer, Pennsylvania Railroad, Philadelphia, Pa.

745. **Boright, W. P.,**
Civil Engineer, Chatham, N. Y.

1445. **Bortin, H.,**
Consulting Valuation Engineer, 325 Central Building, New York City.

705. **Bostwick, W. A.,**
Assistant to President, International Nickel Company, 43 Exchange Place, New York, N. Y.

1951. ***Boucher, N. E.,**
Secretary, Northern White Cedar Association, Minneapolis, Minn.

1894. **★Boughton, V. T.,**
Resident Engineer, Canadian Pacific Railway, Sudbury, Ont., Canada.

862. **Bouton, W. S.,**
Engineer Bridges, Baltimore & Ohio Railroad, Baltimore, Md.

936. **Bowser, E. H.,**
Superintendent Timber Department, Illinois Central Railroad, Grand Central Station, Memphis, Tenn.

1049. **Boyd, G. E.,**
Division Engineer, Delaware, Lackawanna & Western Railroad, Buffalo, N. Y.

1933. **Boyd, James,**
Assistant Engineer, Grand Trunk Railway, Hamilton, Ont., Canada.

1797. **Boykin, R. H.,**
Division Engineer, Erie Railroad, Susquehanna, Pa.

1666. **Bradley, A. C.,**
Division Engineer, Chicago, Rock Island & Pacific Railway, El Reno, Okla.

756. **Brady, S. D.,**
Chief Engineer, Little Kanawha Syndicate Lines, Fairmont, W. Va.

219. **Breckinridge, W. L.,**
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846. **Breed, C. B.,**
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*Associate. ★In Military Service.

543. **Bremner, Geo. H. (*Treasurer*),**

District Engineer, Division of Valuation, Interstate Commerce Commission, Chicago, Ill.

1073. **Brewer, H. H.,**

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1811. ***Brewer, W. A.,**

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1261. **Bridgman, J. N.,**

Assistant Professor of Civil Engineering, University of Nebraska, Lincoln, Neb.

1669. **Briggs, Z. M.,**

Engineer, Pennsylvania Lines, Pittsburgh, Pa.

1484. **Bronson, Miles,**

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823. **Brooke, G. D.,**

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1619. **★Brooke, Richard,**

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920. **Brooks, N. E.,**

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716. **Brooks, Richard,**

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1359. ***Brown, A. V.,**

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925. **Brown, C. B.,**

Assistant General Manager and Chief Engineer, Canadian Government Railways, Moncton, N. B., Canada.

1414. **Brown, C. W.,**

Superintendent, Lehigh & New England Railroad, South Bethlehem, Pa.

367. **Brown, E. C.,**

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1642 **Brown, E. H.,**

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942. **Brown, E. T.,**

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1483. **Brown, H. C., Jr.,**

37 West Van Buren Street, Chicago, Ill.

1067. **Brown, H. W.,**

Assistant Division Engineer, Pennsylvania Lines, Chicago, Ill.

863. **Brown, J. M.,**

Engineer Maintenance of Way, Chicago, Rock Island & Pacific Railway, Topeka, Kansas.

482. **Brown, M. F.,**

Chief Engineer, Boston Bridge Works, 47 Winter Street, Boston, Mass.

709. **Brown, R. K.,**

Engineer Maintenance, Los Angeles & Salt Lake Railroad, Los Angeles, Cal.

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*Associate. ★In Military Service.

1699. **Brown, S. P.,**
Chief Engineer, Mt. Royal Tunnel & Terminal Company, Montreal, Canada.

1741. **Brown, Wm. Lowe,**
Chief Engineer, Buenos Aires Western Railway, Buenos Aires, Argentine.

1222. **Browne, H. L.,**
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1649. **Browne, J. S.,**
Assistant Engineer, New York, New Haven & Hartford Railroad, New Haven, Conn.

682. **Brumley, D. J.,**
Valuation Engineer, Illinois Central Railroad, Chicago, Ill.

1074. **Bruner, A.,**
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410. **Brunner, John,**
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217. **Bryan, C. E.,**
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1683. **Bryan, C. G.,**
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1054. **Bucholtz, Carl,**
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1930. **Buck, C. M.,**
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1668. **Buckalew, S. J.,**
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950. **Budd, Ralph,**
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1326. **Buehler, Walter,**
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594. **Buel, A. W.,**
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1643. **Bulkley, C. W.,**
Interstate Commerce Commission, Kansas City, Mo.

654. **Burgess, G. H.,**
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1257. **Burkhalter, W. E.,**
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646. **Burnett, James,**
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1919. **Burnett, W. S.,**
Engineer Maintenance of Way, Cleveland, Cincinnati, Chicago & St. Louis Railway, Springfield, Ohio.

556. **Burns, J. F.,**
Assistant Engineer Maintenance of Way, Louisville & Nashville Railroad, Louisville, Ky.

991. **Burpee, D. W.,**
Division Engineer, Canadian Northern Railway, Fredericton, N. B., Canada.

820. **Burpee, Moses,**
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973. ***Burpee, T. C.,**
President, Concrete Builders, Ltd., Fredericton, N. B., Canada.

1292. **Burrell, Chas. F.,**
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1189. **Burt, A. M.,**
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773. **Burton, W. J.,**
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621. **Bush, Lincoln,**
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772. **Busteed, F. F.,**
Vancouver, B. C., Canada.

585. **Butterworth, A. C.,**
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1816. **Butterworth, A. S.,**
Assistant Engineer, Missouri Pacific Railroad, St. Louis, Mo.

460. **Byers, C. H.,**
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949. **Byers, M. C.,**
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1530. **Cadarette, Nelson,**
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1908. **Cahill, M. H.,**
General Superintendent, Baltimore & Ohio Railroad, Pittsburgh, Pa.

1676. **Caldwell, A. B.,**
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242. **Camp, W. M.,**
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461. **Campbell, A. Q.,**
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618. **Campbell, J. L.,**
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859. **Canty, J. P.,**
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698. **Caples, M. J.,**
Vice-President, Hocking Valley Railroad, Columbus, Ohio.

1170. **Carleton, H. T.,**
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1152. **Carmichael, John,**
President, W. N. & M. Ry., Martinsburg, W. Va.

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*Associate.

1175. **Carothers, J. B.,**
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1279. **Carpenter, A. W.,**
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1101. **Carpenter, C. L.,**
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1966. **Carpenter, H. R.,**
Assistant Chief Engineer, Missouri Pacific Railroad, St. Louis, Mo.

1397. **★Carson, C. E.,**
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915. **Cartwright, C. E.,**
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1671. **Cary, E. R.,**
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1200. **Case, A. D.,**
Engineer Structures, Boston & Albany Railroad, Boston, Mass.

1601. **Casler, W. A.,**
Pasadena, Cal.

1564. **Cassil, H. A.,**
Engineer Maintenance of Way; Pere Marquette Railroad, Detroit, Mich.

1954. **Cate, C. E.,**
Engineer Maintenance of Way, Southern Pacific Railroad of Mexico, Empalme, Sonora, Mexico.

1373. **Cathey, W. C.,**
Bridge Inspector, Seaboard Air Line, Norfolk, Va.

1651. **★Cattell, W. A.,**
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592. **★Causey, W. B.,**
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899. ***Chace, I. M., Jr.,**
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1691. **Challoner, F. J.,**
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660. **Chamberlain, O. P.,**
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1045. **Chandler, Charles,**
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1005. **Charles, R. S.,**
Layne & Bowler Co., Memphis, Tenn.

1125. **Charnley, Walter,**
Sao Paulo Tramway, Light & Power Company, Brazil, South America.

1450. **Cheney, B. M.,**
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*Associate, ★In Military Service.

1605. **Chenworth, C. J.,**
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1742. ***Cherrington, F. W.,**
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1062. **Christian, W. A.,**
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812. **Christofferson, C. A.,**
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894. **Church, H. M.,**
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1620. ***Church, S. R.,**
Manager Research Department, The Barrett Company, New York, N. Y.

29. **Churchill, Chas. S. (*Past-President*),**
Assistant to President, Norfolk & Western Railway, Roanoke, Va.

1018. ***Clark, C. E.,**
Contracting Engineer, Kansas City, Mo.

939. **Clark, W. A.,**
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1024. **Clement, S. B.,**
Chief Engineer, Temiskaming & Northern Ontario Railway, North Bay, Ont., Canada.

196. **Cleveland, G. C.,**
Chief Engineer, New York Central Railroad, West of Buffalo, Cleveland, Ohio.

977. **Clift, A. E.,**
General Superintendent, Illinois Central Railroad, Chicago, Ill.

389. **Coates, F. R.,**
President, Toledo Railway & Light Company and Toledo & Western Railway Company, Toledo, Ohio.

574. **Coburn, Maurice,**
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1010. **★Cochran, C. W.,**
Galion, Ohio.

1872. **★Coe, C. S.,**
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718. **Colby, J. A.,**
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673. **Coleman, J. F.,**
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1300. **Coles, W. C.,**
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1719. **Colligan, A. F.,**
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1042. **Collin, D. R.,**
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388. **Colpitts, W. W.,**
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1428. **Comstock, A. F.,**
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661. **Conard, C. K.,**
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243. **Condron, T. L.,**
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651. **Congdon, J. P.,**
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953. **Conner, J. K.,**
Chief Engineer, Lake Erie & Western Railroad, Indianapolis Ind.

1065. **Connerton, M. J.,**
Engineer Maintenance of Way, Southern Railway, Western Lines, Chattanooga, Tenn.

701. **Connor, E. H.,**
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897. **Cook, C. C.,**
District Engineer, Baltimore & Ohio Railroad, Wheeling; W. Va.

1947. **Cook, R. A.,**
Valuation Engineer, Chicago & Alton Railroad, Chicago, Ill.

1614. **Cookman, W. H.,**
Architect, Pennsylvania Railroad, Philadelphia, Pa.

94. **Cooley, M. W.,**
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664. **Coombs, R. D.,**
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888. **Coombs, S. E.,**
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1188. **Coon, C. J.,**
Engineer, Grand Central Terminal, New York Central Railroad, East of Buffalo, New York, N. Y.

1504. **Cooper, G. K.,**
Engineering Staff, Chicago Union Station Company, Chicago, Ill.

1367. **Copland, A. C.,**
Office Engineer, Chesapeake & Ohio Railway, Richmond, Va.

1632. **Correll, E. J.,**
Superintendent, Cincinnati, Hamilton & Dayton Railway, Dayton, Ohio.

1920. **Corrigan, G. W.,**
Division Engineer, Southern Pacific Company, Stockton, Cal.

535. **Corthell, A. B.,**
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666. ***Cotter, G. F.,**
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1633. **Cottingham, I. A.,**
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1653. **Coughlin, Daniel,**
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593. **Courtenay, W. H. (*Director*),**
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1625. **Cousins, E. L.,**
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1870. **Cowan, W. A.,**
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202. **Cowper, J. W.,**
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23. **Cox, J. B.,**
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1407. **Crabbs, C. L.,**
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1624. **Crane, E. B.,**
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1503. **Crawford, D. F.,**
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1191. **Crawford, J. E.,**
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1925. **Crea, T. C.,**
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764. **Crear, L. D.,**
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1052. ***Crider, J. L.,**
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1512. **Crocker, R. C.,**
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1451. **Cronican, W. P.,**
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1541. **Cronin, D. W.,**
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1255. **Crowell, F. N.,**
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1970. **Crugar, E. L.,**
District Engineer, Illinois Central Railroad, New Orleans, La.

1047. **Crumpton, Arthur,**
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586. **Cryder, H. M.,**
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1469. ***Cummings, R. A.,**
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485. **Cunningham, A. O.,**
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1553. **Cunningham, W. J.,**
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723. **Curd, W. C.,**
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445. **Curtis, L. G.,**
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370. **Curtis, W. W,**
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1732. **Cutler, D. B.,**
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59. **Dagron, L. L.,**
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1608. **Daley, C. A.,**
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1393. **Dalton, B. J.,**
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1852. **Dana, Chas. H.,**
Office Engineer to Vice-President, Gulf, Colorado & Santa Fe Railway, Galveston, Texas.

1192. **Danes, W. S.,**
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1964. **Dansey, J. W.,**
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1733. **Darden, W. L.,**
Engineer Buildings, Seaboard Air Line, Norfolk, Va.

1249. **Darling, F. S.,**
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22. **Darling, W. L.,**
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647. **Darrow, F. T.,**
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1389. **Davenport, J. A.,**
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1958. Davidson, A. M.,
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484. Davidson, George M.,
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1497. Davies, J. Vipond,
Vice-President and Director, Hudson & Manhattan Railroad New York City.

612. Davis, A. L.,
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1897. Davis, J. M.,
Vice-President, Baltimore & Ohio Railroad, Baltimore, Md.

768. Davis, C. S.,
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1714. Davis, F. H.,
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247. Davis, Garrett,
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34. Davis, J. R. W.,
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1639. Davis, R. P.,
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1868. Davis, R. W.,
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1827. Davis, W. R.,
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679. Dawley, W. M.,
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28. Dawley, W. S.,
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1424. Dawson, J. W.,
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1707. Dawson, W. R.,
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1720. Dayton, C. A.,
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1721. Deal, A. E.,
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368. Deimling, J. F.,
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1768. Delamere, C. T.,
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1002. Delo, C. G.,
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1660. **Demuth, R. E.,**
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918 **Denney, C. E.,**
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398. **Dennis, A. C.,**
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891. **Dennis, Walt,**
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492. **Derr, C. A.,**
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1156. **DeStein, Joseph N.,**
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1767. **Dewees, A. R.,**
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1936. **DeWolf, G. P.,**
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878. **Dick, H. B.,**
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565. **Dickson, J. B.,**
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43. **Didier, Paul,**
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1334. ***Dilks, L. C.,**
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1149. **★Dillabough, J. V.,**
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1874. **Dillenbeck, Clark,**
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1830. **Dixon, H. A.,**
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1253. **Dobbins, J. L.,**
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1716. ***Dodgson, F. L.,**
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1527. **Donahey, J. A.,**
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850. **Dorrance, W. T.,**
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735. **Doucet, A. E.,**
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31. **Dougherty, Curtis,**
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1734. **Doughty, M. H.,**
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676. **Douglas, H. T., Jr.,**
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1709. **Doupe, J. L.,**
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1011. **Downs, J. L.,**
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80. **Downs, L. A. (*Director*),**
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1983. **Doyle, T. L.,**
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1788. **Drake, R. M.,**
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1700. **Draper, E. S.,**
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886. **Drinker, W. W.,**
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1006. **Dubbs, T. L.,**
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877. **Dudley, Dr. P. H.,**
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1196. **Dufour, F. O.,**
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1269. **Duncan, K. B.,**
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493. **Dunham, Charles A.,**
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1798. **Dyke, R. L.,**
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1335. **Earle, Thomas,**
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1429. **Early, P. W.,**
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1201. **Eaton, W. T.,**
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1452. **Eberly, G. F.,**
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960. **★Eck, W. J.,**
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913. **Eddy, C. L.,**
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1941. **Edgerton, H. H.,**
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1236. **Edmondson, G. N.,**
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615. **Edwards, J. H.,**
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889. ***Edwards, L. N.,**
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1211. **Edwards, W. R.,**
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982. **Egan, J. M.,**
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1921. **Elder, J. D.,**
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312. **Elliott, Howard,**
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885. **Elliott, W. H.,**
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578. **Ellis, G. E.,**
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1202. ***Ellis, T. I.,**
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1607. **Ellsworth, F. H.,**
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558. **Elmore, B. T.,**
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1623. **Elmore, J. T.,**
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1071. ***Emerson, Raffe,**
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547. **Endo, Tokichi,**
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1328. ***Entwisle, E. B.,**
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402. **Ericson, E. G.,**
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1886. **Etter, W. K.,**
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1577. **Evans, John,**
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658 **Everham, A. C.,**
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175. **Ewing, C. H.,**
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1076. **Fairbairn, J. M. R.,**
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1159. **Fairchild, Dennison,**
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671. **Fake, C. H.,**
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678. **Falconer, R. C.,**
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1959. **★Farlow, G. B.,**
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1037. **★Fatherson, T. W.,**
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1571. **Faucette, W. D.,**
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588. **Faulkner, E. O.,**
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1531. **Faulkner, L. E.,**
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838. **Feagin, G. W.,**
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1831. **Fee, C. W.,**
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44. **Felt, C. F. W. (*Director*),**
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167. **Felton, S. M.,**
President, Chicago Great Western Railroad, Chicago, Ill.

27. **Fendall, B. T.,**
Secretary, Public Service Commission, Baltimore, Md.

149. **Fernstrom, H.,**
Chief Engineer, Virginian Railway, Norfolk, Va.

309. **Ferris, H. C.,**
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560. **Fine, John H.,**
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★In Military Service.

696. **Finke, W. F. H.,**
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1203. **Finley, W. H.,**
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703. **Fish, J. C. L.,**
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199. **Fisher, S. B.,**
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1690. **Fisher, W. A.,**
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898. **Fisk, C. H.,**
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1547. **Fitzpatrick, P. D.,**
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1961. **Flandreaux, C. S.,**
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194. **Floesch, J. M.,**
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1204. **Flora, G.,**
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1349. **Foote, F. S., Jr.,**
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1286. **Ford, C. F.,**
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406. **Ford, Edward,**
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875. **Ford, R. H.,**
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1973. **★Fordyce, J. R.,**
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1558. **Forrester, Charles,**
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1288. **Foss, Fred E.,**
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1955. **Fox, J. W.,**
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1884. **Fraser, J. E.,**
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1278. **Freeman, F. B.,**
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1950. **Freygang, A. H.,**
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1212. **Frink, E. A.,**
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605. **Fritch, E. H.** (*Secretary*),
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2. **Fritch, L. C.** (*Past-President*),
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1313. ***Fulks, E. B.,**
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906. **Gaines, R. H.,**
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1532. **Galbreath, W. O.,**
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1394. **Gallivan, J. H.,**
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1372. **Galloway, C. W.,**
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1228. ***Gamble, F. C.,**
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1832. **Gammie, R. J.,**
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1427. **Gardner, W. H., Jr.,**
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694. **Garman, H. O.,**
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1432. **Garner, R. D.,**
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1468. **Garrett, R. H.,**
Assistant Engineer, Valuation Department, Seaboard Air Line, Norfolk, Va.

916. **Gatlin, T. H.,**
Assistant to Vice-President, Southern Railway, Washington, D. C.

1271. **Gausewitz, H. A.,**
General Superintendent, Fort Worth & Denver City Railway, Fort Worth, Texas.

1783. **Gaut, J. B.,**
Superintendent Bridges and Buildings, Grand Trunk Railway, Chicago, Ill.

1975. **Gebert, S. C.,**
Valuation Department, Cincinnati, Hamilton & Dayton Railway, Cincinnati, Ohio.

1812. ***Gennet, C. W., Jr.,**
Engineer, R. W. Hunt & Co., Chicago, Ill.

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*Associate.

781. **Gentine, P. F.,**
Superintendent Bridges and Buildings, Missouri Pacific Railroad, Pueblo, Colo.

1163. **Gersbach, Otto,**
Engineer Maintenance of Way, Indiana Harbor Belt Railroad, Gibson, Ind.

1232. **Gibboney, J. H.,**
Chief Chemist, Norfolk & Western Railway, Roanoke, Va.

1509. **Gibbs, A. W.,**
Chief Mechanical Engineer, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

1096. **Gibbs, George,**
Chief Engineer, Electric Traction, Long Island Railroad, New York, N. Y.

1280. **Gibson, H. R.,**
District Engineer, Baltimore & Ohio Southwestern Railroad, Cincinnati, Ohio.

1082. **Gibson, W. S.,**
McKeesport, Pa.

1361. ***Gifford, George E.,**
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1235. **Gilbert, G. H.,**
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882. **Gilcreast, F. W.,**
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1833. **Gillen, U. E.,**
General Superintendent, Grand Trunk Railway, Chicago, Ill.

1949. **Gillies, J. A.,**
Engineer, Southern District, Atchison, Tepeka & Santa Fe Railway, Amarillo, Texas.

985. **Given, W. H.,**
Care General Manager's Office, Chicago, Rock Island & Pacific Railway, Des Moines, Iowa.

1944. **Glass, J. J.,**
Chief Draftsman, Chicago Great Western Railroad, Chicago, Ill.

1411. ***Glass, R. G.,**
Assistant Inspecting Engineer, Illinois Steel Company, 208 South La Salle Street, Chicago, Ill.

1415. **Glover, R. V.,**
Transitman, Delaware, Lackawanna & Western Railroad, Scranton, Pa.

1366. **Godlove, Geo. W., Jr.,**
Assistant Engineer, Atchison, Topeka & Santa Fe Railway, Orrick, Mo.

1001. **Going, A. S.,**
Engineer Construction, Grand Trunk Railway, Montreal, Canada.

1613. **Gold, M. H.,**
Division Engineer, Seaboard Air Line, Savannah, Ga.

198. **Goodale, L. F.,**
Assistant to President, Manila Railroad, Manila, P. I.

801. **Goodell, J. S.,**
Brunswick, Mo.

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*Associate.

1946. **Gooding, W. J.,**
Division Engineer Maintenance of Way, Seaboard Air Line Railway, Jacksonville, Fla.

1786. **★Goodrich, C. M.,**
Designing Engineer, Canadian Bridge Company, Walkerville, Ont., Can.

1622. **Goodrich, H. C.,**
Chief Engineer, Bingham & Garfield Railway, Salt Lake City, Utah

1079. **Gordon, H. L.,**
Engineer of Construction, Monongahela Southern Railroad, Pittsburgh, Pa.

1106. **Gordon, J. A.,**
General Manager, Chicago Great Western Railroad, Chicago, Ill.

1019. **Gowdy, R. C.,**
Chief Engineer, Fort Worth & Denver City Railway, Fort Worth, Texas.

1799. **Graff, C. J.,**
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1388. **★Granbery, J. H.,**
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1055. **Grandy, A. L.,**
Assistant General Manager, Pere Marquette Railroad, Detroit, Mich.

795. **Grant, Gordon,**
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1907. **Grant, E. W.,**
Assistant Engineer Valuation, Eastern Lines, Atchison, Topeka & Santa Fe Railway, Topeka, Kansas.

670. **Grant, W. H.,**
Care Canadian Northern Railway, Toronto, Ont., Canada.

1057. **Graves, G. J.,**
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1526. **Graves, W. F.,**
Chief Engineer, Montreal Tramways Company, Montreal, Canada.

1164. **Gray, Edward,**
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751. **★Green, F. W.,**
Assistant to Vice-President, St. Louis Southwestern Railway, St. Louis, Mo.

1662. **Greenough, H. P.,**
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397. **Greiner, J. E.,**
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463. **Griffith, Lawrence,**
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1885. **Griggs, A. B.,**
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1688. **Grime, E. M.,**
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680. **Griswold, H. C.,**
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1644. **Gross, D. W.,**
Valuation Engineer, Atlantic Coast Line, Wilmington, N. C.

1743. ***Gross, F. H.,**
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1518. **Groves, H. H.,**
Transitman, Pennsylvania Railroad, East Aurora, N. Y.

1449. **Guild, W. A.,**
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506. **★Guppy, B. W.,**
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404. **Gutelius, F. P.,**
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1528. **Guy, F. L.,**
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184. **Gwathmey, W. W.,**
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1963. **Gwyn, J. G.,**
Chief Engineer, Denver & Rio Grande Railroad, Denver, Colo.

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1162. **Hadley, E. A.,**
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1692. **Haggander, G. A.,**
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1296. **Haislip, L. E.,**
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628. **Hale, H. E.,**
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668. **Hallihan, J. P.,**
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1307. ***Hallsted, Jas. C.,**
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1223. **Hamilton, H. F.,**
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611. **Hamilton, Paul,**
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1621. **Hamilton, R. F.,**
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1087. **Hammel, W. A.,**
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1595. **Hammond, C. P.,**
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1877. **Hammond, R. J.,**
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1848. **Hancock, R. R.,**
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1854. **Hand, G. F.,**
Assistant Engineer, New York, New Haven & Hartford Railroad, New Haven, Conn.

1722. **Hand, G. T.,**
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1064. **Hanger, K.,**
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249. **Hanlon, W. B.,**
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1780. **Hanly, F. F.,**
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350. **Hanna, John V.,**
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1543. **Hannaford, A. R.,**
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84. **Harahan, W. J.,**
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933. **Hardin, A. T.,**
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1183. ***Harper, L. D.,**
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908. **Harriman, N. F.,**
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1800. **Harrington, F. F.,**
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923. **Harrington, J. L.,**
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1330. ***Harris, B. B.,**
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1168. **Harris, G. H.,**
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1158. **Harris, G. W.,**
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1634. **Harrison, E. A.,**
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1259. **Harsh, H. H.,**
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357. **Hart, E. E.,**
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1396. **Harvey, D. F.,**

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1897. **Harvey, F. S.,**

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1293. **Harvey, W. C.,**

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747. **Harwood, G. A.,**

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1258. **Hastings, E. M.,**

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182. **Hatch, F. T.,**

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1820. **Hatch, H. A.,**

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1185. **Hawk, A. T.,**

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572. **Hawks, F. W.,**

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1714. **Hayes, Chas. A.,**

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1437. **Hayward, H. M.,**

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1533. **Hazen, H. T.,**

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1485. **Hedgcock, J. A.,**

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1148. **Hegel, G. W.,**

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1926. **Heidenthal, W. C.,**

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1910. **Helvern, D. E.,**

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1911. ***Hench, N. M.,**
Engineer Track Appliances, Carnegie Steel Company, Pittsburgh, Pa.

1378. **Henderson, B.,**
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1766. **Hendricks, K. E.,**
Bridgewater, N. C.

41. **Hendricks, V. K.,**
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1616. **Heritage, C. S.,**
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1822. **Heritage, C. S.,**
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1240. **Herman, B.,**
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1821. **★Hervey, C. L.,**
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1710. **Hestle, J. S.,**
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1089. **Hetzler, H. G.,**
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1554. **Hewes, C. A.,**
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1218. **Hewes, F. S.,**
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1932. **Hewes, John, Jr.,**
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1581. **Hewson, Ewert G.,**
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1264. **Hibbard, I. L.,**
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494. **Hickey, T. H.,**
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530. **Hicks, G. D.,**
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1337. ***Hildreth, P. S.,**
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1751. **Hillary, W. R.,**
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1777. **Hillegass, E. B.,**
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1717. **Hilts, H. E.,**
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1656. **Himmelberger, C. M.,**
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1865. **Hirai, Kikumatsu,**
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1098. ***Hoard, Clarence,**
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344. **Hodgsdon, D. B.,**
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1398. **Hogeland, A. H.,**
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1486. **Holden, J. C.,**
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1765. **Holmes, R. L.,**
Assistant Engineer, Texas & Pacific Railway, Dallas, Texas.

123. **Hood, William,**
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1834. **Hopkins, A. T.,**
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1563. **Hoskins, F. G.,**
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1534. **Hoskins, P. L.,**
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860. **Hotchkiss, L. J.,**
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909. **Houghton, E. R.,**
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1412. **Houser, S. C.,**
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1931. **Howard, R. C.,**
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640. **Howard, R. H.,**
Chief Engineer Maintenance of Way, Wabash Railway, St. Louis, Mo.

1263. **Howe, C. H. R.,**
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1237. **Howes, F. T.,**
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1350. ***Howson, E. T.,**
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160. **Hoyt, C. B.,**
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707. **Hoyt, W. H.,**
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1764. **Hsia, C. T.,**
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1513. **Hubley, R. S.,**
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1400. **★Hudson, H. W.,**
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1256. **Hughes, L. J. F.,**
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1410. **Hughes, W. T.,**
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1979. **Hulsizer, W. H.,**
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683. **Humphrey, Richard L.,**
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105. **Hunt, Robt. W.,**
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1080. **Huntington, C. W.,**
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495. **Huntley, R. L.,**
Chief Engineer (Assistant General Manager), Union Pacific Railroad, Omaha, Neb.

1735. **Hutson, T. M.,**
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714. **Hynes, M. V.,**
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681. **Ibsen, Hans,**
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792. **Inagaki, H.,**
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710. **Inagaki, J.,**
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937. **Ingalls, A. S.,**
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1022. **Ingram, E. L.,**
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1825. **★Irvine, V. R.,**
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1557. **Irving, T. T.,**
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1566. **Irwin, A. Chas.,**
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793. **Irwin, J. C.,**
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145. **Isaacs, John D.,**
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1431. **Isbell, J. M.,**
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1284. **Ives, H. C.,**
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692. **Jackson, Alfred,**
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844. **Jackson, E. D.,**
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546. **Jacoby, H. S.,**
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1775. **Jaekle, W. M.,**
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1224. **James, C. M.,**
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189. **James, L. C.,**
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625. **James, W. A.,**
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741. **Janney, A. D. P.,**
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570. **★Jenkins, J. B.,**
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1492. **Jenks, W. J.,**
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738. **Johns, C. W.,**
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1314. ***Johnson, A. L.,**
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1213. **Johnson, G. P.,**
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858. **Johnson, J. E.,**
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497. **Johnson, J. M.,**
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1250. **Johnson, Maro,**
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1686. **Johnson, Noah,**
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591. **Johnson, Phelps,**
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1020. **Johnson, R. C.,**
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93. **Johnston, A. W.** (*Past-President*),
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1948. **Johnston, C. E,**
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956. **Johnston, D. B.,**
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1383. **Johnston, T. S.,**
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253. **Jonah, F. G.,**
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(In Military Service.)

1637. **Jones, F. A.,**
General Roadmaster, Missouri Pacific Railroad, Wynne, Ark.

91. **Jones, Paul,**
Superintendent, Pennsylvania Lines, Toledo, Ohio.

1778. **Jones, R.,**
Superintendent, Galveston, Harrisburg & San Antonio Railway, Victoria, Texas.

1606. **Jones, William,**
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1672. **Jones, W. A.,**
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620. **Jordan, S. A.,**
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1880. **Jordan, W. F.,**
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1953. **Jump, S. C.,**
Assistant Engineer, Illinois Central Railroad, Chicago, Ill.

1360. ***Jurgensen, D. F.,**
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1205. **Justice, G. H.,**
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1403. **Kaighn, Charles,**
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142. **Kalk, C. N.,**
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1346. ***Kammerer, A. L.,**
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1104. **★Katte, E. B.,**
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1012. **Kawa-e, Hideo,**
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1867. **Keegan, J. F.,**
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1603. **Kegler, W. C,**
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1587. **Kellett, W. P.,**
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1881. **Kelly, W. W.,**
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86. **Kelley, Howard G. (*Past-President*),**
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798. **Kenrick, G. A.,**
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1548. **Kent, Gilbert R.,**
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1943. **Keough, R. E.,**
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1476. **Kerr, D. J.,**
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952. **Ketchum, M. S.,**
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677. **Khuen, Richard,**
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1319. ***Kimball, G. H.,**
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1784. **Kimble, W. P.,**
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1736. ***Kinney, W. M.,**
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1473. **Kirby, J. L.,**
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1776. **Kirkbride, W. H.,**
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1506. **Kirkpatrick, C. S.,**
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1882. **Kissell, J. E.,**
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106. **Kittredge, George W.** (*Past-President*),
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561. **Knickerbocker, C. E.,**
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1225. **Knight, Harold,**
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1381. **Knight, W. B.,**
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1592. **Knolles, W. J.,**
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1701. **Knowles, C. R.,**
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1568. **Koren, Jess D.,**
Division Engineer, Northern Pacific Railway, Spokane, Wash.

1723. **Krause, L. G.,**
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*Associate.

1139. **Krumm, T. Z.,**
975 South High Street, Columbus, Ohio.

8. **Kruttschnitt, Julius,**
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835. ***Kuehn, A. L.,**
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1835. **Kuntz, G. T.,**
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1782. **Kurokochi, S.,**
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930. **LaBach, Paul M.,**
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1401. ***Lacher, W. S.,**
Associate Engineering Editor, Railway Age Gazette, Chicago, Ill.

1737. **Lacy, L. H.,**
Care Chief Engineer, St. Louis Southwestern Railway, Tyler, Texas.

802. **Lahmer, J. A.,**
Drainage Engineer, Missouri Pacific Railroad, St. Louis, Mo.

1573. **Laird, E. P.,**
Superintendent, Atlantic Coast Line Railroad, Richmond, Va.

1243. **Laird, H. G.,**
Superintendent Timber Preservation, Atlantic Coast Line Railroad, Gainesville, Fla.

1781. **Lakin, F. D.**
Division Engineer, Erie Railroad, Meadville, Pa.

1151. **★Lamphere, F. E.,**
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52. **Landon, H. C.,**
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1922. **Landorph, E. L.,**
Engineer Water Service, Canadian Pacific Railway, Winnipeg, Man., Canada.

635. **Lane, E. G.,**
Engineer Maintenance of Way, Baltimore & Ohio Railroad, Western Lines, Cincinnati, Ohio.

653. **Lane, H. A.,**
Chief Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

1938. **Lang, P. G., Jr.,**
Assistant Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

746. ***Lannan, L. E.,**
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1421. **Larsen, Albert,**
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1574. ***Larson, C. M.,**
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1626. ***Larson, C. G. E.,**
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1730. **Lassiter, E. J.,**
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1738. **Latham, R. L.,**
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887. **★Lavis, Fred,**
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1090. **Lawton, L. C.,**
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656. **Layfield, E. N.,**
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944. **Layng, F. R.,**
Engineer of Track, Bessemer & Lake Erie Railroad, Greenville, Pa.

1687. **Leatherbury, F. W.,**
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124. **Lee, E. H.,**
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837. **Lee, Frank,**
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732. **Leffler, B. R.,**
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717. **Lehn, Henry,**
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631. **Leighty, J. R.,**
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1092. **Leisenring, J. G. M.,**
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979. **Lemond, J. S.,**
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338. **Lewis, C.,**
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1836. **Lewis, C. M.,**
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790. **Lewis, D. O.,**
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759. **Lewis, E. R.,**
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1912. **Lewis, P. S.,**
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1728. **Lindenthal, Gustav,**
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*Associate. ★In Military Service.

49. **Lindsay, C. E.** (*Director*),
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1112. **Linnbaum, J. W.,**
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1940. ***Little, J. G.,**
Assistant Engineering Editor, Railway Age Gazette, New York City.

1179. **Lloyd, H. A.,**
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1113. **Lockwood, R. J.,**
Vice-President and General Manager, Appalachicola Northern Railway, Port St. Joe, Fla.

861. **Long, M. A.,**
Assistant to Chief Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

1404. **Lonnbladh, L. F.,**
Chief Engineer, Missouri, Kansas & Texas Railway, Dallas, Texas.

1869. **Lord, W. H.,**
Assistant Engineer, Atlantic Coast Line Railroad, Jacksonville, Fla.

1391. **Losh, C. F.,**
Assistant Engineer, Norfolk & Western Railway, Roanoke, Va.

1888. **Lothholz, H. C.,**
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441. **Loweth, C. F.,**
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815. **Lownsbury, F. W.,**
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1654. **Lowry, H. K.,**
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1724. **Lozier, W. L.,**
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146. **Lum, D. W.,**
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1562. **Lyon, Arthur S.,**
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1413. **MacFarland, H. B.,**
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1409. **Mackenzie, A. C.,**
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1678. **MacKintosh, C. D.,**
Superintendent, Canadian Pacific Railway, Medicine Hat, Alberta, Canada.

715. **MacLean, F. W.,**
Inspecting Engineer, New Zealand Government Railways, Wellington, N. Z.

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896. **MacMartin, James,**
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990. **Macomb, J. deN.,**
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1952. **Macpherson, A. W.,**
Acting Chief Engineer, San Francisco-Oakland Terminal Railways, Oakland, Cal.

53. **Macy, E. C.,**
Care Stone & Webster Corporation, Boston, Mass.

1364. **Maher, John,**
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1898. **Maischaider, A. F.,**
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934. **Maney, Thomas,**
Louisville, Ky.

577. **Mann, B. H ,**
Signal Engineer, Missouri Pacific Railroad, St. Louis, Mo.

1793. **Manson, E. F.,**
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1802. **Manspeaker, L. V.,**
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1569. **Marble, Frank B.,**
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391. **Marchbanks, James,**
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1206. **Markham, E. L.,**
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171. **Markley, A. S.,**
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1502. **Marsh, M. M.,**
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1507. **Martin, B. C.,**
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986. **Martin, L. B.,**
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1004. **Martin, R. H.,**
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1697. **Maruyama, Y.,**
Engineering Department, South Manchurian Railways, Darien, China.

366. **Mason, J. D.,**
General Foreman Bridges and Buildings, Richmond, Fredericksburg & Potomac Railroad, Fredericksburg, Va.

1942. **Masters, F. H.,**
Division Engineer, Elgin, Joliet & Eastern Railway, Gary, Ind.

1416. **Massenburg, W. G.,**
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662. **Mather, Richard,**
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1750. **Mathews, J. D.,**
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1107. **★Mattice, G. L.,**
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1447. **McBride, J. S.,**
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1238. **McCalman, D. S.,**
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1693. **McCarvel, T. J.,**
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1380. **McClain, J. B.,**
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1792. **McClanahan, S. L.,**
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1535. **McComb, R. J.,**
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1555. **McCooe, David,**
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987. **McCormick, R. L.,**
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1443. **McCree, A. A.,**
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1892. **McDade, W. F.,**
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1384. **McDonald, B. M.,**
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11. **McDonald, Hunter** (*Past-President*),
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1299. **McGinnis, F. T.,**
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183. **McGonagle, W. A.,**
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1664. **McGrew, John A.,**
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1862. **McGuigan, Francis H., Jr.,**
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644. **McIntosh, D. T.,**
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1702. **McKey, D. M,**
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1684. **McLeod, H. W.,**
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972. **McMaster, R. T.,**
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1903. **McNab, J. V.,**
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166. **McNab, William** (*Past-President*),
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1855. **McNally, J. F.,**
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1070. **McNeil, J. E.,**
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1976. **McQuarrie, M. K.,**
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1744. **McVay, C. M.,**
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1338. ***Mead, C. A.,**
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581. **Meade, J. M.,**
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1763. **Mercier, A. T.,**
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1363. ***Mercier, Paul E.,**
Chief Engineer and City Surveyor, Montreal, Canada.

1803. **Merrill, F. A.,**
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1219. **Merritt, Frank,**
Chief Engineer, Gulf, Colorado & Santa Fe Railway, Galveston, Texas.

1871. **Merwin, C. E.,**
Chief Engineer, Detroit Terminal Railroad, Detroit, Mich.

17. **Michel, William,**
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739. **Miesse, C. H.,**
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770. **Milburn, J. H.,**
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1239. **Miller, A. P.,**
Resident Engineer, Canadian Government Railways, Glen Miller, Ont., Canada.

1663. **Miller, Crosby,**
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725. **Miller, C. H.,**
President, Miller Engineering Company, Southern Trust Building, Little Rock, Ark.

1878. **Miller, R. M.,**
Assistant Engineer, Virginian Railway, Norfolk, Va.

579. **Millett, Geo. C.,**
Assistant to Chief Engineer, Coast Lines, Atchison, Topeka & Santa Fe Railway, Los Angeles, Cal.

1711. **Mills, A. L.,**
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502. **Milner, B. C.,**
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1252. **Milner, W. L.,**
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1850. **Mims, Lewis,**
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1590. **Mitchell, George A.,**
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1769. **Mitchell, L. A.,**
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1887. **Mitchell, R. S,**
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1035. **Mitchell, W. M.,**
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418. **Mock, J. C.,**
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232. **Modjeski, Ralph,**
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284. **★Molitor, F. A.,**
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1900. **Moncure, W. A.,**
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1050. **★Monsarrat, C. N.,**
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178. **Montfort, R.,**
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606. **Montzheimer, A.,**
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967. **Moodie, W. T.,**
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596. **Moore, C. H.,**
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758. **Moore, G. L.,**
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1819. **Moore, H. J.,**
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1117. **Moore, J. W.,**
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318. **Moore, W. H.,**
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1924. ***Moore, W. S.,**
Chief Engineer, Cleveland Frog and Crossing Company, Cleveland, Ohio.

1327. ***Mordecai, A.,**
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1246. **Morgan, O. K.,**
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566. **Morkill, W. L.,**
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1289. **Morphy, L. G.,**
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1770. **Morrill, C. R.,**
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1789. **Morrison, E. C.,**
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172. **Morrison, J. M.,**
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1475. **Morrison, W. W.,**
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527. **Morse, C. A.** (*First Vice-President*),
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1536. **Morse, W. L.,**
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1301. **Motley, P. B,**
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279. **Mountain, G. A.,**
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1665. **Mudge, H. U.,**
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905. **Mullen, Jos.,**
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1703. **Murr, L. A,**
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1386. **Murray, J. F.,**
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1615. **Murray, W. A.,**
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1083. **Murray, W. S,**
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855. **Myers, J. B.,**
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1905. **Nagle, J. C.,**
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963. **Neafie, A. J.,**
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648. **Neff, F. H.,**
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45. **Nelson, J. C.,**
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1977. **Nelson, J. P.,**
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1982. **Niemeyer, C. H.,**
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1174. **Neubert, J. V.,**
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847. **Newbegin, P. C.,**
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479. ***Newhall, W. S.,**
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1371. **Newhouse, C. E.,**
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645. **Newton, A. W.,**
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1923. **Nichols, J. A., Jr.,**
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36. **Nicholson, F. L.,**
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1821. **Nisbet, W. C.,**
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1593. **Norman, Charles E.,**
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1422. ***Norris, Geo. L.,**
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1137. **Norris, W. H ,**
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1609. ***North, A. T.,**
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1207. **Nuelle, J. H.,**
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1579. **Nugent, Francis,**
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1467. **Nye, C. M.,**
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1480. **O'Connor, Howard,**
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1739. **O'Donnell, J. E.,**
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1466. **Ogle, W. F.,**
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519. **Ohmra, T.,**
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1462. **Oliver, E. W ,**
Assistant to Chief Engineer, Canadian Northern Railway, Toronto, Ont., Canada.

1969. **Olson, E. H.,**
Office Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kan.

1971. ***Ondarcho, S. C.,**
Supervisor of Track, Philadelphia, Bethlehem & New England Railroad, Bethlehem, Pa.

1298. **Onderdonk, J. R.,**
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1980. **Ono, Rioye,**
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784. **Oren, F. B.,**
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749. **Ormerod, G. H.,**
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616. **Orr, D. K ,**
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663. **Orrock, J. W.,**
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1978. **Osgood, H. A.,**
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617. **Ostrom, J. N.,**
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1749. **Otto, J. A.,**
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1889. **Owen, A. E.,**
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1457. **Owen, A. W.,**
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1866. **Owre, Oliver,**
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1896. **Oxnard, H. W.,**
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1837. **Pace, D. P.,**
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1704. **Paine, R. R.,**
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1214. **Palmer, G. P.,**
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1675. **Palmer, H, A.,**
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208. **Paquette, C. A.,**
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307. **Paret, M. P.,**
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1084. **Park, W. L.,**
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842. **Parker, Chas. J.,**
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1291. **Parker, R. J.,**
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769. **Parker, W. A.,**
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1058. **Parrish, F. J.,**
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1913. **Parsons, O. V.,**
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503. **Parsons, R. S.,**
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845. **Passel, H. F.,**
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789. **Patenall, F. P.,**
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1221. **Patterson, C. B.,**
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180. **Patterson, F. M.,**
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1180. **Patterson, J. C.,**
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983. ***Patterson, J. C.,**
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567. **Peabody, J. A.,**
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971. **Pearce, R. M.,**
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551. **Pearson, E. J.,**
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1516. **Pearson, J. W.,**
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1838. **Pearson, R. L.,**
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1287. **Pederson, H.,**
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1839. **Perkins, C. D.,**
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1242. **Perkins, Lee,**
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890. **Perkins, L. M.,**
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1762. **Perrin, A. W.,**
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667. **Peter, John S.,**
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779. **Peters, J. F.,**
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733. **Petersen, W. H.,**
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826. **Petri, Philip,**
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1572. **Peyton, John Howe,**
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38. **Pfafflin, E. H.,**
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1488. **Pfau, J. W.,**
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743. **Pfeifer, H. J.,**
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1514. **Pfleging, F. W.,**
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1589. **Phelps, Henry A.,**
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302. **Phillips, H. C.,**
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1840. **Phillips, S. B.,**
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1539. **Pickles, J. L.,**
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1860. **Pinner, Guy,**
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1813. **Pittman, T. M., Jr.,**
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851. **Plumley, G. S.,**
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235. **Poland, W. B.,**
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1761. **Porter, D. A.,**
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415. **Porter, H. T.,**
Chief Engineer, Bessemer & Lake Erie Railroad, Greenville, Pa.

1027. **Porter, J. W.,**
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552. **Post, C. C., Jr.,**
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1352. ***Powell, E. W.,**
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1408 **Powell, T. B.,**
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602. **Pratt, R. B,**
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1231. **Price, O. R.,**
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1956. **Priest, R. N.,**
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1144. ***Prime, A. C.,**
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1171. **Prior, J. H.,**
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504. **Puder, F. R.,**
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544. **Purdon, C. D.,**
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1194. **Purdy, W. F.,**
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946. **Quigley, C. N.,**
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1549. **Quigley, Thomas,**
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1285. **Ramage, J. C.,**
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1266. **★Ramsey, C. W. P.,**
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1760. **Ramsey, F. R.,**
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427. **Ranno, F. W.,**
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1333. **★Rathjens, G. W.,**
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655. **Ray, G. J.,**
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1928. **Ray, W. M.,**
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1254. **Raymond, E.,**
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1794. **Reagan, J. H.,**
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1826. **Reamer, R. V.,**
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607. **Redgrave, W. B,**
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1146. **Redinger, C. A.,**
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1537. ***Reeves, C. E.,**
Ellsworth, Barrows & Reeves, Buffalo, N. Y.

639. **Reichmann, Albert,**
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1171. **★Reid, J. M.,**
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719. **Reid, J. M.,**
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1274. **Reid, J. W.,**
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1902. **Reimann, Robert,**
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1103. **Reinholdt, J. H.,**
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1712. **Reinke, F. J.,**
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1075. **Reisler, E. T.,**
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1038. **Rettinghouse, H.,**
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1111. **Rex, Geo. E.,**
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721. **Rhea, Frank,**
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1914. **Rhodes, E. M.,**
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1059. **Rice, S. B.,**
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1392. ***Richan, G. F.,**
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1048. **Richards, D. W.,**
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1498. **Richardson, C. P.,**
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1459. **Richardson, J. H.,**
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1604. **Richardson, J. J.,**
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1729. **Richey, A. S.,**
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1041. **Richey, C. W.,**
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630. **Rickert, O.,**
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910. **Rickie, J. H.,**
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1132. **Ridgway, A. O.,**
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1901. **Riley, D. A.,**
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1304. ***Ritter, L. E.,**
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1814. **Roach, J. A.,**
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1841. **Robinson, J. S.,**
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988. **Robinson, W. M ,**
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1369. **Rodenbaugh, H. N.,**
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1804. ***Roehm, G. E.,**
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1051. **Rohbock, W. L.,**
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1650. **Roof, W. R ,**
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413. **Rose, L. S.,**
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1124. **★Rosher, E. M.,**
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1490. **Ross, H. T.,**
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635. **Rossiter, L. P.,**
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360. **Rote, R. O.,**
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355. **Rudd, A. H.,**
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1842. **Ruff, J. S.,**
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1524. **Ruffin, Chas. L.,**
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1641. **Rupp, W. H.,**
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1658. **Ruppert, C. L.,**
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1251. **Rutledge, R. A.,**
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1362. ***Rys, C. F. W.,**
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1436. **Sattley, R. C.,**
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1169. **Savage, J. R.,**
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1417. **Sawyer, Mott,**
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520. **Schall, F. E.,**
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1828. **Schofield, John,**
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1805. **Schram, I. H.,**
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938. **Schuerman, W. H.,**
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840. **Schulz, W. F.,**
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819. **Schwed, John F.,**
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1757. **Schwinn, F. S.,**
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524. **Scribner, G. H., Jr.,**
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744. **Seaman, H. B.,**
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931. **Seddon, W. L.,**
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386. **Sesser, John C.,**
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1806. **Sessions, O. H.,**
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1785. **Sexton, J. R.,**
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1460. **Sheldon, C. S.,**
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1674. **Shepard, R. B., Jr.,**
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1875. **Shepherd, F. C.,**
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1276. **Sherwin, F. A.,**
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1655. **Shields, A. C.,**
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880. **Shillinger, John G.,**
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1342. ***Shipley, G. B.,**
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1627. ***Shipley, L. B.,**
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1131. **Shipman, E. H.,**
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523. **Shurtleff, A. K.,**
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1779. **Siefer, F. M.,**
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1771. **Sikes, Z. H.,**
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1740. **★Silcox, L. E.,**
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1060. **Silliman, Charles,**
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1645. **Sills, J. M ,**
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1847. **Sinnickson, G. R.,**
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1546. **Sisson, F. P.,**
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1706. **Sloan, E. D,**
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1510. **Sloggett, L. O.,**
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1823. **Small, C. C,**
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1525. **Smith, A. Bromley,**
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922. **Smith, C. E,**
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1294. **Smith, D. W.,**
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1696. **Smith, E. W.,**
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1030. **Smith, Sherman,**
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1272. **★Smith, W. W.,**
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1915. **Snyder, G. W.,**
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1561. **Snyder, H. G.,**
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1177. **Sommerville, D. L.,**
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1873. **Sparke, Walter,**
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1420. **Spear, P. H.,**
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1095. **Spell, W. A.,**
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825. **Spencer, C. H.,**
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1694. **Spencer, H. B ,**
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1465. **Spencer, W. T.,**
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1745. Stafford, S. C.,
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1718. Stanley, Harvey,
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1673. Stansbury, H. E.,
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1515. *Stark, C. W.,
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352. **Stevens, Thos. S.,**
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852. **Stewart, A. F.,**
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1324. ***Stewart, A. H.,**
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533. **Stimson, F. J.,**
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1143. **Stocker, J. A.,**
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1130. **Stone, A. H.,**
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1844. **Stone, L. I.,**
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74. **Storey, W. B.** (***Past-President***),
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1458. **Story, George, Jr.,**
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1387. **Stradley, Carl,**
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1856. ***Strong, J. B.,**
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1036. **Strouse, W. F.,**
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786. **Syme, Geo. F.,**
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1138. **Sympson, H. T.,**
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622. **Taber, E. G.,**
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1817. ***Taft, J. R.,**
Civil Engineer, New York, N. Y.

691. **Talbot, A. N. (*Director*),**
Professor of Municipal and Sanitary Engineering and in charge of Theoretical and Applied Mechanics, University of Illinois, Urbana, Ill.

929. **Talcott, G. R.,**
Resident Engineer, Atchison, Topeka & Santa Fe Railway, Shattuck, Okla.

498. **Talcott, H. R.,**
Chairman, Valuation Committee, Baltimore & Ohio Railroad, Baltimore, Md.

1594. ***Tallman, Paul B.,**
Engineer, Warren & Wetmore, 16 East Forty-seventh Street, New York, N. Y.

1479. **Tallyn, L. L.,**
Division Engineer, Delaware, Lackawanna & Western Railroad, Scranton, Pa.

1713. **Tams, W. F.,**
Assistant Engineer, Chesapeake & Ohio Railway, Richmond, Va.

446. **Tanabe, S.,**
Professor of Civil Engineering, University of Kyote, Kyote, Japan.

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*Associate.

1281. **Tani, Naonobu,**
Principal Assistant Engineer, South Manchurian Railway, Darien, Manchuria, China.

439. **Taussig, J. E,**
Assistant to President, Wabash Railway, St. Louis, Mo.

1172. **Taylor, C. M.,**
Superintendent Creosoting Plants, Philadelphia & Reading Railway and Central Railroad of New Jersey, Port Reading, N. J.

1602. **Taylor, D. M.,**
Assistant Engineer, Wheeling & Lake Erie Railroad, Cleveland, Ohio.

1088. **Taylor, E. B., Jr.,**
Division Engineer, Pennsylvania Lines, Pittsburgh, Pa.

1433. **Taylor, Edwy L,**
Contract Agent, New York, New Haven & Hartford Railroad, New Haven, Conn.

1023. **Taylor, Frank**
Right-of-Way and Lease Agent, Canadian Pacific Railway, Montreal, Canada.

1229. **Taylor, J. J.,**
Superintendent Bridges and Buildings, Kansas City Southern Railway, Texarkana, Texas.

1689. **★Taylor, J. L., Jr.,**
Assistant Engineer, Pennsylvania Lines West, Pittsburgh, Pa.

1167. **Taylor, R. T.,**
Trainmaster, Northern Pacific Railway, Duluth, Minn.

1635. **Taylor, W. C,**
Assistant Engineer, Oregon-Washington Railroad & Navigation Company, Portland, Ore.

1494. **Teal, J. E.,**
Assistant Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

1134. **Tebbetts, G. E.,**
Bridge Engineer, Kansas City Terminal Railway, Kansas City, Mo.

1898. **Teders, J. G,**
Assistant Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

1631. ***Teesdale, C. H.,**
In Charge of Wood Preservation, Forest Products Laboratory, Madison, Wis.

1072. **Temple, E. B,**
Assistant Chief Engineer, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

629. **Temple, H. H.,**
18 West Seventh Street, Cincinnati, Ohio.

1094. ***Thomas, Charles E.,**
Waukesha, Wis.

821. **Thompson, A. W.,**
Vice-President, Baltimore & Ohio Railroad, Baltimore, Md.

969. **Thompson, F. L.,**
Assistant Chief Engineer, Illinois Central Railroad, Chicago, Ill.

290. **Thompson, W. S.,**
Division Engineer, Pennsylvania Railroad, Sunbury, Pa.

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*Associate.

1599. **Thornton, H. W.,**
General Manager, Great Eastern Railway of England, Liverpool Station, London, England.

1099. **Thrower, D. W.,**
Assistant Valuation Engineer, Illinois Central Railroad, Chicago, Ill.

742. **Tinker, G. H.,**
Bridge Engineer, New York, Chicago & St. Louis Railroad, 516 Columbia Building, Cleveland, Ohio.

1748. **Titcomb, H. B.,**
Maintenance of Way Assistant, Southern Pacific Company, San Francisco, Cal.

1086. **★Tomlinson, A. T.,**
Inspector of Small Arms, Lindsay Arsenal, Lindsay, Ont., Canada.

1056. **Toops, G. N.,**
Engineer Maintenance of Way, Muskogee, Oklahoma & Gulf Railway, Muskogee, Okla.

1227. **Tordella, John,**
Division Engineer, Baltimore & Ohio Railroad, Garrett, Ind.

1069. **Towne, W. J.,**
Assistant General Manager, Chicago & Northwestern Railway, 226 West Jackson Boulevard, Chicago, Ill.

1210. **★Townsend, T. G.,**
Timber Treating Inspector, Southern Railway, Washington, D. C.

1440. **Trabue, H. H.,**
Assistant Chief Engineer and Assistant Real Estate Agent, Nashville, Chattanooga & St. Louis Railway, Nashville, Tenn.

941. **Trapnell, W.,**
Chief Engineer and Superintendent, Coal & Coke Railway, Elkins, W. Va.

215. **Tratman, E. E. R.,**
Associate Editor, Engineering News-Record, 202 Ellis Avenue, Wheaton, Ill.

1491. **Traugott, A. M.,**
Division Engineer, Virginian Railway, Princeton, W. Va.

1542. **Trenholm, J. B.,**
Engineer Roadway, Atlantic Coast Line, Rocky Mount, N. C.

1190. **Trimble, A. F.,**
Special Agent, Office General Manager, Erie Railroad, New York City.

67. **Trimble, Robert** (*Past-President*),
Chief Engineer Maintenance of Way, Northwest System, Pennsylvania Lines West of Pittsburgh, Pittsburgh, Pa.

1295. ***Trumbull, M. K.,**
Vice-President, National Lumber & Creosoting Company, Kansas City, Mo.

359. **Turk, J. E.,**
Assistant to General Manager, Philadelphia & Reading Railway, Reading, Pa.

477. **Turneaure, F. E.,**
Dean, College of Engineering, University of Wisconsin, Madison, Wis.

1808. **Turner, A. M.,**
District Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, Columbus, Ohio.

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*Associate. ★In Military Service.

1376. **Turner, F. P.,**
Bridge Engineer, Norfolk & Western Railway, Roanoke, Va.

1918. **Tuthill, G. C.,**
Acting Bridge Engineer, Michigan Central Railroad, Detroit, Mich.

379. **Tuthill, Job.,**
Chief Engineer, Pere Marquette Railroad, Detroit, Mich.

112. **Tweedy, R. B.,**
President and Treasurer, Marinette, Tomahawk & Western Railroad, Tomahawk, Wis.

364. **Tye, W. F.,**
Consulting Engineer, 76 Sherbrooke Street West, Montreal, Canada.

U

1551. **Underwood, B. A.,**
Resident Engineer, Atchison, Topeka & Santa Fe Railway, Pawhuska, Okla.

155. **Underwood, F. D.,**
President, Erie Railroad, 50 Church Street, New York, N. Y.

1482. ***Unger, J. S.,**
Manager, Central Research Bureau, Carnegia Steel Company, Pittsburgh, Pa.

V

1584. **Van Auken, A. M.,**
Assistant Engineer Costs, Michigan Central Railroad, Detroit, Mich.

1303. ***Van Auken, K. L.,**
1824 Lytton Building, Chicago, Ill.

1184. **Vance, W. H.,**
Engineer Maintenance of Way, St. Louis-Southwestern Railway, Tyler, Texas.

1596. **Vandersluis, W. M.,**
Signal Engineer, Illinois Central Railroad, Chicago, Ill.

1147. **Van Hagan, L. F.,**
Associate Professor, University of Wisconsin, Madison, Wis.

600. ***Van Houten, R. A.,**
1201 McCormick Building, Chicago, Ill.

1340. ***Vanneman, C. R.,**
Consulting Engineer, 555 Providence Street, Albany, N. Y.

103. **Vaughan, Geo. W.,**
Engineer Maintenance of Way, New York Central Railroad, East of Buffalo, New York, N. Y.

1365. ***Vollintine, J. L.,**
Railway Underwriters, 1413 Insurance Exchange, Chicago, Ill.

573. **von Schrenk, Dr. H.,**
Consulting Timber Engineer, St. Louis, Mo.

1891. **von Sprecken, Frank,**
Division Engineer, Atlantic Coast Line Railway, Waycross, Ga.

1883. **Votey, J. W.,**
Dean, College of Engineering, University of Vermont, Burlington, Vt.

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*Associate.

W

924. **Waddell, J. A. L.,**
Consulting Engineer, Kansas City, Mo.

767. ***Wadsworth, J. E.,**
Division Engineer, American Bridge Company, 30 Church Street, New York, N. Y.

1756. **Wagner, S. T.,**
Chief Engineer, Philadelphia & Reading Railway, Philadelphia, Pa.

1746. **Waid, G. S.,**
Vice-President and General Manager, Sunset Central Lines, Houston, Texas.

522. **Waite, H. M.,**
City Manager, Dayton, Ohio.

122. **Walker, I. O.,**
Division Engineer, Western & Atlantic Railroad, Atlanta, Ga.

1028. **Walker, W. K.,**
Engineer Maintenance of Way, Wabash Railway, Montpelier, O.

1142. **Wallace, D. A.,**
108 Gloucester Street, Ottawa, Canada.

57. **Wallace, H. U.,**
Vice-President, Western Light & Power Company, Boulder, Colo.

3. **Wallace, John F.** (*Past-President—Honorary Member*),
President, Westinghouse, Church, Kerr & Company, 37 Wall Street, New York, N. Y.
Chairman, Terminal Commission of Chicago, 559 Insurance Exchange, Chicago, Ill.

540. **Wallace, W. A.,**
44 Washington Boulevard, Oak Park, Ill.

932. **Walling, V. R.,**
Principal Assistant Engineer, Chicago & Western Indiana Railroad, 67 Dearborn Station, Chicago, Ill.

1818. **Walter, J. W.,**
Box. No. 416, Shattuck, Okla.

1522. **Warden, R. E.,**
Assistant Engineer, Missouri Pacific Railroad, Atchison, Kan.

1390. **Waring, O. T.,**
Superintendent, Atlantic Coast Line Railroad, Waycross, Ga.

1157. **Warren, G. T.,**
Toronto, Ohio.

1580. **Warren, Walter D.,**
Engineer, New York, New Haven & Hartford Railroad, Lines East, Boston, Mass.

188. **Washington, L. A.,**
Commissioner of Public Works, Paducah, Ky.

1640. **★*Wasson, J. H.,**
Recorder, Division of Valuation, Interstate Commerce Commission, Chicago, Ill.

1863. **Waterman, Joseph H.,**
Superintendent of Timber Preservation, Chicago, Burlington & Quincy Railroad, Galesburg, Ill.

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*Associate. ★In Military Service.

1809. **Waters, R. P.,**
302 Park Street, Bridgeport, Conn.

1758. **Watkins, R. C.,**
Superintendent, Galveston, Harrisburg & San Antonio Railway, San Antonio, Texas.

1659. **Watson, F. E.,**
Trenton, Mo.

1275. **★Watson, P. J., Jr.,**
Assistant Engineer, Chicago & Alton Railroad, Bloomington, Ill.

1377. ***Watson, W. J.,**
Consulting Engineer, 1150 Leader Building, Cleveland, Ohio.

421. **Weatherly, E. P.,**
416 Railway Exchange, Kansas City, Mo.

1652. **Weaver, C. E.,**
Engineer Maintenance of Way, Central of Georgia Railroad, Savannah, Ga.

1464. **Weaver, H. A.,**
Division Engineer, New York, New Haven & Hartford Railroad, Boston, Mass.

507. **★Webb, G. H.,**
Chief Engineer, Michigan Central Railroad, Detroit, Mich.

1193. **Webb, Walter Leslie**
District Engineer, Chicago, Milwaukee & St. Paul Railway, Chicago, Ill.

686. **★Webb, Walter Loring,**
Public Utility Engineer, Philadelphia, Pa.

306. **Webster, William R.,**
Consulting and Inspecting Engineer, 411 Walnut Street, Philadelphia, Pa.

1755. **Weeks, O.,**
Assistant Superintendent, Southern Pacific Company, Ogden, Utah.

1927. **Weidel, Joseph,**
Valuation Engineer, Atchison, Topeka & Santa Fe Railway, Chicago, Ill.

1325. ***Weidman, W. R.,**
12958 Emerson Avenue, Cleveland, Ohio.

1576. **Weir, J. M.,**
Chief Engineer, Kansas City Southern Railway, Kansas City, Mo.

1646. **Welling, J. W.,**
Roadmaster, Yazoo & Mississippi Valley Railroad, Greenville, Miss.

514. **Wells, L. W.,**
Assistant to General Manager and Chief Engineer, Texas Midland Railroad, Terrell, Texas.

1916. **Welty, H. T.,**
Engineer of Structures, New York Central Railroad, East of Buffalo, New York City.

127. **Wendt, Edwin F. (*Past-President*),**
Member Engineering Board, Division of Valuation, Interstate Commerce Commission, Washington, D. C.

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*Associate. ★In Military Service.

1472. **West, R. W.,**
Division of Valuation, Interstate Commerce Commission, Chicago, Ill.

1754. **Wester, C. A.,**
Division Engineer, Southern Pacific Company, Dunsmuir, Cal.

1861. **Westfall, C. C.,**
Engineer of Bridges, Illinois Central Railroad, Chicago, Ill.

590. ***Weston, C. V.,**
332 South Michigan Avenue, Chicago, Ill.

1570. **Wharf, A. J.,**
Chief Engineer, Peoria & Pekin Union Railway, Peoria, Ill.

904. **Wheaton, F. L.,**
Division Engineer, Delaware, Lackawanna & Western Railroad, Binghamton, N. Y.

69. **Wheaton, L. H.,**
Consulting Engineer, Halifax, Nova Scotia.

1849. **Wheelwright, Barton,**
Acting Signal Engineer, Grand Trunk Railway, Montreal, Canada.

1277. **Wherry, B. T.,**
Assistant Engineer, Northern Pacific Railway, St. Paul, Minn.

66. **White, I. F.,**
Engineer Maintenance of Way, Chicago Great Western Railroad, Chicago, Ill.

1040. **White, R. C.,**
Superintendent, Missouri Pacific Railroad, Wynne, Ark.

1234. **White, R. M.,**
Superintendent, Delaware, Lackawanna & Western Railroad, Easton, Pa.

1845. **White, T. E.,**
Supervisor of Track, Louisiana & Arkansas Railway, Minden, La.

1773. **Whiteside, J. F.,**
Roadmaster, Southern Railway, Western Lines, Danville, Ky.

1552. **Whiting, Chas. L.,**
Superintendent, Chicago, Milwaukee & St. Paul Railway, Lewistown, Mont.

1499. **Whitney, T. B.,**
Milford, Pike County, Pa.

1290. **Whitney, W. C.,**
Newtonville, Mass.

564. **Wickhorst, M. H.,**
Engineer of Tests, Rail Committee, Chicago, Ill.

903. **Wicksteed, H. K.,**
Chief Engineer of Surveys, Canadian Northern Railway, Toronto, Canada.

782. ***Wiggin, E. W.,**
Consulting Engineer, 506 Cutler Building, New Haven, Conn.

911. **Wiggins, W. D.,**
Valuation Engineer, Pennsylvania Lines West of Pittsburgh, Pittsburgh, Pa.

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*Associate.

874. **Wilgus, H. S.,**
Engineer Maintenance of Way, Pittsburg, Shawmut & Northern Railroad, Angelica, N. Y.

185. **★Wilgus, W. J.,**
Consulting Engineer, 165 Broadway, New York, N. Y.

854. **Wilkinson, J. W.,**
Assistant Engineer, New York, Chicago & St. Louis Railroad, Cleveland, Ohio.

1186. **Willard, W. C.,**
408 Chittenden Avenue, Columbus, Ohio.

1759. **Williams, A. P.,**
Division Engineer, Baltimore & Ohio Railroad, Connellsville, Pa.

1441. **Williams, C. C.,**
Professor of Railway Engineering, University of Kansas, Lawrence, Kan.

1598. **Williams, H. C.,**
Chief Engineer Construction, Louisville & Nashville Railroad, Louisville, Ky.

271. **Williams, H. R.,**
Vice-President, Chicago, Milwaukee & St. Paul Railway, 42 Broadway, New York, N. Y.

1560. **Williams, K. G.,**
Assistant Engineer, Valuation Department, Chicago, Rock Island & Pacific Railway, Memphis, Tenn.

689. **Williams, S. N.,**
Professor-Emeritus, Cornell College of Iowa, 734 Fair Oaks Avenue, Oak Park, Ill.

32. **Williams, W. D.,**
Chief Engineer, Cincinnati Northern Railroad, Van Wert, Ohio.

783. **Willis, R. W.,**
Engineer, Illinois District, Chicago, Burlington & Quincy Railroad, 547 West Jackson Boulevard, Chicago, Ill.

610. **Willoughby, J. E.,**
Chief Engineer, Atlantic Coast Line, Wilmington, N. C.

811. **Wilson, A. O.**
Division Engineer, Seaboard Air Line Railway, Charleston, S. C.

9. **Wilson, C. A.,**
Consulting Engineer, 529 Burns Avenue, Cincinnati, Ohio.

1358. ***Wilson, G. L.,**
Engineer Maintenance of Way, Twin City Rapid Transit Company, Minneapolis, Minn.

1316. ***Wilson, P. H.,**
Consulting Engineer, Devon, Pa.

1851. **Wilson, R. G.,**
Assistant Division Engineer, Erie Railroad, Jersey City, N. J.

1405. **Wilson, W. W.,**
Division Engineer, Gulf, Colorado & Santa Fe Railway, Galveston, Texas.

806. **Wiltsee, W. P.,**
Assistant to Chief Engineer, Norfolk & Western Railway, Roanoke, Va.

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*Associate. ★In Military Service.

474. **Wirth, A. A.,**
Supervising Engineer, Pennsylvania Lines, Pittsburgh, Pa.

945. **Wishart, J. G.,**
Office Engineer, Chicago, Rock Island & Pacific Railway, 802 LaSalle Station, Chicago, Ill.

1311. ***Wolfel, P. L.,**
Chief Engineer, McClintic-Marshall Company, Rankin, Pa.

1419. **Wonson, S. L.,**
Bridge Engineer, Missouri Pacific Railroad, St. Louis, Mo.

555. **Wood, B. A.,**
Chief Engineer, Mobile & Ohio Railroad, Mobile, Ala.

1774. **Wood, E. A.,**
Draftsman, Texas & Pacific Railway, Dallas, Texas.

1115. ***Woodhouse, S. J.,**
Maceo No. 29 (Altos), Sagua La Grande, Cuba.

1824. **Woodruff, R. E.,**
Superintendent, Erie Railroad, Youngstown, Ohio.

848. **Woods, A. A.,**
Superintendent, Southern Railway, New Orleans, La.

278. **Woods, H. A.,**
Assistant Chief Engineer, Grand Trunk Pacific Railway, Winnipeg, Man., Canada.

395. **Worcester, J. R.,**
Consulting Engineer, 79 Milk Street, Boston, Mass.

1893. **Worthing, E. E.,**
Signal Engineer, Southern Pacific Company, Houston, Texas.

704. **Worthington, B. A.,**
President, Cincinnati, Indianapolis & Western Railroad, Indianapolis, Ind.

1385. ***Wysor, W. W.,**
Assistant Chief Engineer, United Railways and Electric Company, Baltimore, Md.

Y

1145. **Yager, Louis,**
Engineer Maintenance of Way, Northern Pacific Railway, St. Paul, Minn.

456. **Yamaguchi, J.,**
Maintenance of Way Department, Imperial Government Railways, Tokyo, Japan.

1846. **Yardley, C. F.,**
Division Engineer, New York, New Haven & Hartford Railroad, Hartford, Conn.

1216. **Yates, J. J.,**
Bridge Engineer, Central Railroad of New Jersey, 143 Liberty Street, New York, N. Y.

1727. **Young, D. R.,**
Assistant Engineer, Delaware, Lackawanna & Western Railroad, Buffalo, N. Y.

595. **Young, R. C.,**
Chief Engineer, Lake Superior & Ishpeming Railway and Munising, Marquette & Southeastern Railways, Marquette, Mich.

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*Associate.

Z

1425. ***Ziegweid, A. B.,**

Senior Civil Engineer, Division of Valuation, Interstate Commerce Commission, Chicago, Ill.

207. **Zeising, A.,**

President, American Bridge Company, Chicago, Ill.

614. **Zinn, A. S.,**

5023 Champlain Avenue, Chicago, Ill.

1110. ***Zook, M. A.,**

Resident Engineer, Division of Valuation, Interstate Commerce Commission, Washington, D. C.

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*Associate.

MEMBERSHIP AND MILEAGE OF RAILWAYS REPRESENTED IN THE AMERICAN RAILWAY ENGINEERING ASSOCIATION

Name of Road and Membership.	*Members.*	*Mileage.*
Akron, Canton & Youngstown Railway	1	70
J. A. Donahey, General Superintendent and Chief Engineer, Akron, Ohio.		
Algoma Central & Hudson Bay Railway	1	419
R. S. McCormick, Chief Engineer, Sault Ste. Marie, Ont., Canada.		
Apalachicola Northern Railroad	1	102
R. J. Lockwood, Vice-President and General Manager, Port St. Joe, Fla.		
Arizona Extension Railroad	1	...
C. C. Small, Chief Engineer, Clarkdale, Ariz.		
Arkansas & Louisiana Midland Railway	1	102
Edward Ford, President, New Orleans, La.		
Assam-Bengal Railway	1	775
G. H. Ormerod, Division Engineer, Lumding, Assam, India.		
Atchison, Topeka & Santa Fe Railway System	58	10,649
W. B. Storey, Vice-President, Chicago, Ill.		
C. F. W. Felt, Chief Engineer, System, Chicago, Ill.		
A. F. Robinson, Bridge Engineer, System, Chicago, Ill.		
Joseph Weidel, Valuation Engineer, Chicago, Ill.		
H. B. MacFarland, Engineer of Tests, Chicago, Ill.		
E. O. Faulkner, Manager Tie and Timber Department, Los Angeles, Cal.		
Geo. E. Rex, Manager Treating Plants, Topeka, Kan.		
E. A. Harrison, Architect, Chicago, Ill.		
Thos. S. Stevens, Signal Engineer, Topeka, Kan.		
J. deN. Macomb, Office Engineer, Chicago, Ill.		
J. C. Beye, Locating Engineer, Chicago, Ill.		
W. C. Baisinger, Assistant Engineer on Construction, Chicago, Ill.		
C. W. Baldridge, Assistant Engineer, Chicago, Ill.		
J. W. Dansey, Assistant Engineer, Chicago, Ill.		
R. J. Parker, General Manager, Western Lines, Amarillo, Texas.		
T. H. Sears, General Superintendent, Amarillo, Texas.		
F. M. Bisbee, Chief Engineer, Western Lines, Amarillo, Texas.		
J. A. Gillies, Engineer, Southern District, Amarillo, Texas.		
J. A. Roach, Division Engineer, East Las Vegas, N. M.		
F. S. Hewes, Pilot Engineer, Amarillo, Texas.		
I. L. Hibbard, Assistant General Manager, Los Angeles, Cal.		
G. W. Harris, Chief Engineer, Coast Lines, Los Angeles, Cal.		
Geo. C. Millett, Assistant to Chief Engineer, Los Angeles, Cal.		
J. E. McNeil, Inspector Track and Roadway, Los Angeles, Cal.		
E. E. Ball, Division Engineer, Fresno, Cal.		
Frank Merritt, Chief Engineer, Galveston, Texas.		
Chas. A. Dana, Office Engineer to Vice-President, Galveston, Texas.		

Name of Road and Membership.	*Members.*	*Mileage.*
Atchison, Topeka & Santa Fe—Continued.		
J. L. Starkie, Office Engineer, Galveston, Texas.		
C. A. Ashbaugh, Division Engineer, Cleburne, Texas.		
F. W. Leatherbury, Division Engineer, Temple, Texas.		
W. W. Wilson, Division Engineer, Galveston, Texas.		
W. G. Massenburg, Acting Engineer, Galveston, Texas.		
J. M. Isbell, Engineering Department, Galveston, Texas.		
E. Raymond, General Superintendent, Topeka, Kan.		
R. A. Rutledge, Chief Engineer, Eastern Lines, Topeka, Kan.		
G. J. Bell, Engineer, Western District, Newton, Kan.		
M. C. Blanchard, Engineer, Eastern District, Topeka, Kan.		
E. H. Olson, Office Engineer, Topeka, Kan.		
K. B. Duncan, Valuation Engineer, Topeka, Kan.		
E. W. Grant, Assistant Engineer Valuation, Topeka, Kan.		
J. M. Meade, Special Engineer, Topeka, Kan.		
W. K. Etter, Superintendent, Arkansas City, Kan.		
J. F. McNally, Assistant Superintendent, Chanute, Kan.		
C. M. Buck, Division Engineer, Topeka, Kan.		
G. J. Graves, Division Engineer, Dodge City, Kan.		
W. A. Guild, Division Engineer, Chillicothe, Ill.		
H. A. Hatch, Division Engineer, Chanute, Kan.		
D. E. Helvern, Division Engineer, Pueblo, Colo.		
L. J. F. Hughes, Division Engineer, Herington, Kan.		
L. C. Lawton, Division Engineer, Newton, Kan.		
R. N. Priest, Division Engineer, Kansas City, Mo.		
Geo. W. Godlove, Jr., Assistant Engineer, Orrick, Mo.		
A. B. Griggs, Assistant Engineer, Topeka, Kan.		
G. T. Kuntz, Assistant Engineer, Topeka, Kan.		
H. W. Oxnard, Assistant Engineer, Topeka, Kan.		
G. R. Talcott, Resident Engineer, Shattuck, Okla.		
B. A. Underwood, Resident Engineer, Pawhuska, Okla.		
J. W. Stewart, Engineering Department, Topeka, Kan.		
Atlanta, Birmingham & Atlantic Railroad	2	641
L. L. Beall, Chief Engineer, Atlanta, Ga.		
W. A. Spell, Assistant Engineer, Atlanta, Ga.		
Atlantic Coast Line Railroad...........................	13	4,577
J. E. Willoughby, Chief Engineer, Wilmington, N. C.		
C. J. Chenworth, Assistant to Third Vice-President, Wilmington, N. C.		
C. M. James, Engineer of Construction, Wilmington, N. C.		
E. B. Hillegass, Engineer Roadway, Savannah, Ga.		
L. L. Sparrow, Engineer Roadway, Jacksonville, Fla.		
J. B. Trenholm, Engineer Roadway, Rocky Mount, N. C.		
E. P. Laird, Superintendent, Richmond, Va.		
O. T. Waring, Superintendent, Waycross, Ga.		
D. W. Gross, Valuation Engineer, Wilmington, N. C.		
R. B. Shepard, Jr., Office Engineer, Wilmington, N. C.		
Frank von Sprecken, Division Engineer, Waycross, Ga.		
W. H. Lord, Assistant Engineer, Jacksonville, Fla.		
H. G. Laird, Superintendent Timber Preservation, Gainesville, Fla.		
Baltimore & Ohio Railroad System.........................	78	4,692
A. W. Thompson, Vice-President, Baltimore, Md.		
J. M. Davis, Vice-President, Baltimore, Md.		
R. N. Begien, General Manager, Eastern Lines, Baltimore, Md.		
M. H. Cahill, General Superintendent, Pittsburgh, Pa.		
J. F. Keegan, General Superintendent, Wheeling, W. Va.		
J. A. Spielmann, Assistant to General Superintendent, Pittsburgh, Pa.		
G. D. Brooke, Superintendent, Cumberland, Md.		
F. G. Hoskins, Superintendent, Wheeling, W. Va.		
D. F. Stevens, Superintendent, Newark, Ohio.		
S. A. Jordan, Assistant Superintendent, Brunswick, Md.		

Name of Road and Membership. *Members.* *Mileage.*

Baltimore & Ohio—Continued.

E. V. Smith, Assistant Superintendent, New Castle, Pa.
H. A. Lane, Chief Engineer, Baltimore, Md.
J. E. Greiner, Consulting Engineer, Baltimore, Md.
Earl Stimson, Engineer Maintenance of Way, Baltimore, Md.
M. A. Long, Assistant to Chief Engineer, Baltimore, Md.
H. R. Talcott, Chairman, Valuation Committee, Baltimore, Md.
J. B. Jenkins, Valuation Engineer, Baltimore, Md.
Paul Didier, Principal Assistant Engineer, Pittsburgh, Pa.
C. C. Cook, District Engineer, Wheeling, W. Va.
Richard Mather, District Engineer, Huntington, W. Va.
J. B. Myers, District Engineer, Baltimore, Md.
Philip Petri, District Engineer, Pittsburgh, Pa.
W. B. Redgrave, District Engineer, St. George, S. I., N. Y.
W. S. Bouton, Engineer Bridges, Baltimore, Md.
J. R. Onderdonk, Engineer of Tests, Baltimore, Md.
F. P. Patenall, Signal Engineer, Baltimore, Md.
J. H. Milburn, Chief Draftsman, Baltimore, Md.
F. J. Angier, Superintendent Timber Preservation, Baltimore, Md.
Lester Bernstein, Supervisor Traffic Statistics, Baltimore, Md.
G. W. Andrews, Assistant to Engineer Maintenance of Way, Baltimore, Md.
Theo. Bloecher, Jr., Division Engineer, Philadelphia, Pa.
E. H. Barnhart, Division Engineer, Wheeling, W. Va.
E. T. Brown, Division Engineer, Grafton, W. Va.
C. E. Bryan, Division Engineer, Parkersburg, W. Va.
H. M. Church, Division Engineer, Baltimore, Md.
D. W. Cronin, Division Engineer, New Castle, Pa.
G. F. Eberly, Division Engineer, Grafton, W. Va.
F. F. Hanly, Division Engineer, Cumberland, Md.
H. H. Harsh, Division Engineer, Pittsburgh, Pa.
John Tordella, Division Engineer, Garrett, Ind.
A. P. Williams, Division Engineer, Connellsville, Pa.
W. T. Hughes, Assistant Division Engineer, Cumberland, Md.
Richard Brooke, Assistant Engineer, Baltimore, Md.
P. G. Lang, Jr., Assistant Engineer, Baltimore, Md.
R. C. Howard, Assistant Engineer, Huntington, W. Va.
W. M. Ray, Assistant Engineer, Cleveland, Ohio.
J. T. Andrews, Assistant Engineer, Baltimore, Md.
L. E. Haislip, Assistant Engineer, Wheeling, W. Va.
E. D. Jackson, Assistant Engineer, Baltimore, Md.
W. C. Nisbet, Assistant Engineer, Baltimore, Md.
Robert Reimann, Assistant Engineer, Relay, Md.
E. M. Rhodes, Assistant Engineer, Baltimore, Md.
W. F. Strouse, Assistant Engineer, Baltimore, Md.
J. E. Teal, Assistant Engineer, Baltimore, Md.
J. G. Teders, Assistant Engineer, Baltimore, Md.
J. H. Adamson, Field Engineer, Meyersdale, Pa.
John Hewes, Jr., Field Engineer, Huntington, W. Va.
D. A. Riley, Field Engineer, Baltimore, Md.
W. C. Coles, Pilot Engineer, Wheeling, W. Va.
M. F. Steinberger, Lighterage Agent, St. George, S. I., N. Y.
J. W. Linnbaum, Engineering Department, Baltimore, Md.

Baltimore & Ohio Southwestern Railroad.

C. W. Galloway, Vice-President and General Manager, Western Lines, Cincinnati, Ohio.
E. G. Lane, Engineer Maintenance of Way, Cincinnati, Ohio.
A. M. Kinsman, Engineer of Construction, Cincinnati, Ohio.
F. D. Batchellor, District Engineer, Cincinnati, Ohio.
H. R. Gibson, District Engineer, Cincinnati, Ohio.

Name of Road and Membership.	*Members.*	*Mileage.*
Baltimore & Ohio—Continued.		
H. B. Dick, District Valuation Engineer, Cincinnati, Ohio.		
A. H. Freygang, Division Engineer, Seymour, Ind.		
C. H. R. Howe, Division Engineer, Chillicothe, Ohio.		
C. E. Newhouse, Assistant Division Engineer, Seymour, Ind.		
William Archer, Assistant Engineer, Cincinnati, Ohio.		
A. M. Davidson, Assistant Engineer, Cincinnati, Ohio.		
G. B. Farlow, Assistant Engineer, Cincinnati, Ohio.		
W. P. Ball, Assistant Division Engineer, Cincinnati, Ohio.		
Baltimore & Ohio Chicago Terminal.		
L. G. Curtis, District Engineer, Chicago, Ill.		
G. P. Palmer, Division Engineer, Chicago, Ill.		
F. S. Harvey, Assistant Engineer, Chicago, Ill.		
F. E. Lamphere, Assistant Engineer, Chicago, Ill.		
Bangor & Aroostook Railroad	2	625
Moses Burpee, Chief Engineer, Houlton, Maine.		
P. C. Newbegin, Maintenance Engineer, Houlton, Maine.		
Bessemer & Lake Erie Railroad	2	209
H. T. Porter, Chief Engineer, Greenville, Pa.		
F. R. Layng, Engineer of Track, Greenville, Pa.		
Bingham & Garfield Railway	1	29
H. C. Goodrich, Chief Engineer, Salt Lake City, Utah.		
Boston & Albany Railroad	8	393
F. B. Freeman, Chief Engineer, Boston, Mass.		
A. D. Case, Engineer Structures, Boston, Mass.		
J. C. Irwin, Assistant Valuation Engineer, Boston, Mass.		
L. G. Morphy, Designing Engineer, Boston, Mass.		
G. W. Abbott, Division Engineer, Boston, Mass.		
W. B. Knight, Division Engineer, Springfield, Mass.		
E. S. Draper, Assistant Engineer, Boston, Mass.		
J. H. Richardson, Draftsman, Newtonville, Mass.		
Boston & Maine Railroad	9	2,481
W. J. Cunningham, President's Assistant, Boston, Mass.		
A. B. Corthell, Chief Engineer, Boston, Mass.		
B. W. Guppy, Engineer of Structures, Boston, Mass.		
F. A. Merrill, Engineer Maintenance of Way, Concord, N. H.		
F. C. Shepherd, Principal Assistant Engineer, Boston, Mass.		
H. R. Sargent, Assistant Valuation Engineer, Boston, Mass.		
R. J. Hammond, Chief Draftsman, Boston, Mass.		
J. E. Fraser, Assistant Engineer, Winchester, Mass.		
J. P. Canty, Supervisor Bridges and Buildings, Fitchburg, Mass.		
Branford Steam Railroad	1	...
Clarence Blakeslee, Treasurer and Consulting Engineer, New Haven, Conn.		
Brooklyn Rapid Transit System	1	71
C. L. Crabbs, Engineer Way and Structures, Brooklyn, N. Y.		
Buenos Aires Western Railway	1	...
Wm. Lowe Brown, Chief Engineer, Buenos Aires, Argentine.		

Name of Road and Membership.	*Members.*	*Mileage.*
Buffalo, Rochester & Pittsburgh Railway	1	586
E. F. Robinson, General Manager, Rochester, N. Y.		
Burma Railroad of India	3	...
Walter Sparke, District Engineer, Burma, India.		
W. J. Knolles, Assistant Engineer, Burma, India.		
J. H. Rickie, Assistant Engineer, Rangoon, Burma.		
Butte, Anaconda & Pacific Railway	1	76
T. J. McCarvel, Superintendent Maintenance of Way and Structures, Anaconda, Mont.		
Canadian Government Railways	4	3,803
C. B. Brown, Assistant General Manager and Chief Engineer, Moncton, N. B., Canada.		
J. J. Richardson, Assistant Engineer, Moncton, N. B., Canada.		
F. X. Amoss, Resident Engineer, Corinth, Ont., Canada.		
A. P. Miller, Resident Engineer, Glen Miller, Ont., Canada.		
Canadian Northern Railway	11	7,545
A. F. Stewart, Chief Engineer, Toronto, Ont., Canada.		
H. K. Wicksteed, Chief Engineer of Surveys, Toronto, Ont., Canada.		
E. W. Oliver, Assistant to Chief Engineer, Toronto, Ont., Canada.		
W. H. Grant, Engineering Department, Toronto, Ont., Canada.		
H. T. Hazen, District Engineer, Toronto, Ont., Canada.		
D. O. Lewis, District Engineer, Victoria, B. C., Canada.		
John Schofield, Architect, Winnipeg, Man., Canada.		
W. T. Moodie, Division Engineer, Winnipeg, Man., Canada.		
D. W. Burpee, Division Engineer, Fredericton, N. B., Canada.		
R. A. Baldwin, Assistant Engineer, Toronto, Ont., Canada.		
H. T. Ross, Assistant Engineer, Fort William, Ont., Canada.		
Canadian Pacific Railway	20	12,994
John G. Sullivan, Chief Engineer, Western Lines, Winnipeg, Man., Canada.		
J. M. R. Fairbairn, Assistant Chief Engineer, Montreal, Canada.		
A. C. Mackenzie, Engineer Maintenance of Way, Montreal, Canada.		
P. B. Motley, Engineer Bridges, Montreal, Canada.		
Frank Lee, Principal Assistant Engineer, Winnipeg, Man., Canada.		
J. W. Orrock, Principal Assistant Engineer, Montreal, Canada.		
C. T. Delamere, Engineer Construction, Montreal, Canada.		
W. A. James, Engineer of Construction, Winnipeg, Man., Canada.		
C. D. MacKintosh, Superintendent, Medicine Hat, Alta,. Canada.		
J. L. Doupe, Chief Surveyor, Western Lines, Winnipeg, Man., Canada.		
Frank Taylor, Right-of-Way and Lease Agent, Montreal, Canada.		
R. E. Keough, Assistant Engineer Maintenance of Way, Montreal, Canada.		
F. W. Alexander, Division Engineer, Calgary, Alta., Canada.		
H. A. Dixon, Division Engineer, Vancouver, B. C., Canada.		
J. C. Holden, Division Engineer, Winnipeg, Man., Canada.		

Name of Road and Membership.	*Members.*	*Mileage.*
Canadian Pacific—Continued.		
J. V. McNab, Roadmaster, Bassano, Alta., Canada. ada.		
E. L. Landorph, Engineer Water Service, Winnipeg, Man., Canada.		
V. T. Boughton, Resident Engineer, Ludburg, Ont., Can.		
E. B. Skeels, Resident Engineer, Lethbridge, Alta., Canada.		
A. Bromley Smith, Assistant Engineer, Montreal, Canada.		
H. W. McLeod, Assistant Engineer, Winnipeg, Man., Canada.		
Canton-Samshire Railway	1	...
R. C. Johnson, Superintendent Way and Works, Canton, China.		
Carolina, Clinchfield & Ohio Railway	1	291
O. K. Morgan, Engineer in Charge, Johnson City, Tenn.		
Central Aguirre Company	1	...
C. L. Carpenter, Manager, Central Aguirre, Porto Rico.		
Central of Georgia Railway	4	2,024
L. W. Baldwin, Vice-President and General Manager, Savannah, Ga.		
C. P. Hammond, Special Engineer, Savannah, Ga.		
C. E. Weaver, Engineer Maintenance of Way, Savannah, Ga.		
J. W. Fox, Valuation Engineer, Savannah, Ga.		
Central New England Railway	1	304
J. H. Gallivan, Construction Engineer, Poughkeepsie, N. Y.		
Central Railway of Guatemala	1	...
D. B. Hodgsdon, General Manager, Guatemala City, Guatemala, C. A.		
Central Railroad of New Jersey	7	642
W. G. Besler, President and General Manager, New York City.		
A. E. Owen, Chief Engineer, New York City.		
C. H. Stein, Superintendent, Jersey City, N. J.		
J. J. Yates, Bridge Engineer, New York City.		
R. V. Reamer, Engineer Maintenance of Way, Jersey City, N. J.		
H. Bortin, Valuation Department, New York City.		
C. M. Himmelberger, Assistant Trainmaster, Jersey City, N. J.		
Central Vermont Railway	3	586
J. M. Morrison, Engineer and Superintendent Structures, St. Albans, Vt.		
P. D. Fitzpatrick, Valuation Engineer and General Roadmaster, St. Albans, Vt.		
J. E. O'Donnell, Assistant Engineer, St. Albans, Vt.		
Chesapeake & Ohio Railway	8	2,371
L. B. Allen, General Superintendent, Huntington, W. Va.		
Crosby Miller, Bridge Engineer, Richmond, Va.		
C. W. Johns, Engineer Branch Lines, Richmond, Va.		
A. C. Copland, Office Engineer, Richmond, Va.		
J. P. Nelson, Valuation Engineer, Richmond, Va.		
T. B. Powell, Valuation Department, Richmond, Va.		
Edward Gray, Hamlet, W. Va.		
W. F. Tams, Assistant Engineer, Richmond, Va.		

Name of Road and Membership.	*Members.*	*Mileage.*
Chicago & Alton Railway	6	1,052
H. T. Douglas, Jr., Chief Engineer, Chicago, Ill.		
J. W. Reid, Bridge Engineer, Chicago, Ill.		
R. A. Cook, Valuation Engineer, Chicago, Ill.		
L. V. Manspeaker, Assistant Engineer, Springfield, Ill.		
H. H. Swisher, Assistant Engineer, Chicago, Ill.		
P. J. Watson, Jr., Assistant Engineer, Bloomington, Ill.		
Chicago & Eastern Illinois Railroad	3	1,282
L. C. Hartley, Chief Engineer, Chicago, Ill.		
J. S. McBride, Principal Assistant Engineer, Chicago, Ill.		
A. S. Markley, Master Carpenter, Danville, Ill.		
Chicago & Illinois Western Railroad	1	17
O. P. Chamberlain, Vice-President and General Manager, Chicago, Ill.		
Chicago & Northwestern Railway	6	8,423
R. H. Aishton, President, Chicago, Ill.		
W. J. Towne, Assistant General Manager, Chicago, Ill.		
W. H. Finley, Chief Engineer, Chicago, Ill.		
J. A. Peabody, Signal Engineer, Chicago, Ill.		
G. M. Davidson, Chemist and Engineer of Tests, Chicago, Ill.		
J. S. Robinson, Division Engineer, Chicago, Ill.		
Chicago & Western Indiana Railroad	3	77
H. G. Hetzler, President, Chicago, Ill.		
E. H. Lee, Vice-President and Chief Engineer, Chicago, Ill.		
V. R. Walling, Principal Assistant Engineer, Chicago, Ill.		
Chicago, Burlington & Quincy Railroad	7	9,366
A. W. Newton, Chief Engineer, Chicago, Ill.		
W. L. Breckinridge, Engineer Maintenance of Way, Chicago, Ill.		
F. T. Darrow, Engineer Maintenance of Way, Lincoln, Neb.		
B. M. Cheney, General Inspector Permanent Way, Chicago, Ill.		
G. A. Haggander, Bridge Engineer, Chicago, Ill.		
R. W. Willis, Engineer, Illinois District, Chicago, Ill.		
Joseph H. Waterman, Superintendent Timber Preservation, Galesburg, Ill.		
Chicago Great Western Railroad	10	1,496
S. M. Felton, President, Chicago, Ill.		
J. A. Gordon, General Manager, Chicago, Ill.		
C. G. Delo, Chief Engineer, Chicago, Ill.		
T. W. Fatherson, Engineer Maintenance of Way, Des Moines, Iowa.		
I. F. White, Engineer Maintenance of Way, Chicago, Ill.		
W. C. Harvey, First Assistant Engineer, Chicago, Ill.		
W. R. Roof, Assistant Engineer Bridges, Chicago, Ill.		
H. H. Edgerton, Assistant Engineer, Chicago, Ill.		
J. J. Glass, Chief Draftsman, Chicago, Ill.		
W. O. Galbreath, Engineering Department, Chicago, Ill.		
Chicago, Indianapolis & Louisville Railway	1	622
A. S. Kent, Chief Engineer, Chicago, Ill.		
Chicago Junction Railway	1	168
G. W. Hegel, Chief Engineer, Chicago, Ill.		

Name of Road and Membership.	*Members.*	*Mileage.*
Chicago, Milwaukee & St. Paul Railway	8	10,287
H. R. Williams, Vice-President, New York City.		
C. F. Loweth, Chief Engineer, Chicago, Ill.		
Mott Sawyer, Superintendent, Mason City, Iowa.		
Chas. L. Whiting, Superintendent, Lewistown, Mont.		
H. C. Lothholz, Engineer of Design, Chicago, Ill.		
Walter Leslie Webb, District Engineer, Chicago, Ill.		
E. B. Crane, Assistant Engineer, Chicago, Ill.		
A. Chas. Irwin, Assistant Engineer, Chicago, Ill.		
Chicago, Rock Island & Pacific Railway	30	7,829
C. A. Morse, Chief Engineer, Chicago, Ill.		
F. T. Beckett, Engineer Maintenance of Way, El Reno, Okla.		
J. M. Brown, Engineer Maintenance of Way, Topeka, Kan.		
W. H. Petersen, Engineer Maintenance of Way, Des Moines, Iowa.		
R. C. Sattley, Valuation Engineer, Chicago, Ill.		
I. L. Simmons, Bridge Engineer, Chicago, Ill.		
A. T. Hawk, Architect, Chicago, Ill.		
R. H. Ford, Engineer Track Elevation, Chicago, Ill.		
H. K. Lowry, Signal Engineer, Chicago, Ill.		
Daniel Coughlin, Superintendent, Rock Island, Ill.		
H. P. Greenough, Superintendent, Dalhart, Texas.		
C. L. Ruppert, Superintendent, Trenton, Mo.		
J. G. Wishart, Office Engineer, Chicago, Ill.		
Francis Nugent, Office Engineer, El Reno, Okla.		
C. F. Ford, Supervisor Tie and Timber Department, Chicago, Ill.		
A. C. Bradley, Division Engineer, El Reno, Okla.		
K. Hanger, Division Engineer, El Dorado, Ark.		
S. L. McClanahan, Division Engineer, Goodland, Kan.		
H. P. Greenough, Superintendent, Dalhart, Texas.		
B. B. Shaw, Division Engineer, Little Rock, Ark.		
A. C. Shields, Division Engineer, Trenton, Mo.		
W. H. Given, General Manager's Office, Des Moines, Iowa.		
A. J. Bisbee, Assistant Engineer, Valuation Department, Chicago, Ill.		
K. G. Williams, Assistant Engineer, Valuation Department, Memphis, Tenn.		
Garrett Davis, Assistant Engineer, Chicago, Ill.		
Paul M. LaBach, Assistant Engineer, Chicago, Ill.		
C. P. Richardson, Assistant Engineer, Chicago, Ill.		
H. L. Browne, Masonry Inspector, Des Moines, Iowa.		
E. F. Manson, Master Carpenter, Manly, Iowa.		
W. F. Ogle, Draftsman, Chicago, Ill.		
Chicago, St. Paul, Minneapolis & Omaha Railway	1	1,753
H. Rettinghouse, Chief Engineer, St. Paul, Minn.		
Chicago, Terre Haute & Southeastern Railway	2	374
E. H. Pfafflin, Chief Engineer, Chicago, Ill.		
F. R. Puder, Assistant Engineer, Chicago, Ill.		
Cincinnati, Findlay & Fort Wayne Railway	1	91
J. B. Carothers, Receiver, Findlay, Ohio.		
Cincinnati, Hamilton & Dayton Railway	5	1,013
E. J. Correll, Superintendent, Dayton, Ohio.		
F. J. Parrish, Division Engineer, Dayton, Ohio.		
H. G. Snyder, Division Engineer, Dayton, Ohio.		
S. C. Gebert, Valuation Department, Cincinnati, Ohio.		
John Maher, Assistant Engineer, Cincinnati, Ohio.		
Cincinnati, Indianapolis & Western Railway	3	381
B. A. Worthington, President, Indianapolis, Ind.		
M. V. Hynes, General Superintendent, Indianapolis, Ind.		
H. F. Passel, Chief Engineer, Indianapolis, Ind.		

Name of Road and Membership.	*Members.*	*Mileage.*
Cincinnati Northern Railroad. (See New York Central Lines.)		
Cleveland, Cincinnati, Chicago & St. Louis Railway. (See New York Central Lines.)		
Coal & Coke Railway Company W. Trapnell, Chief Engineer, Elkins, W. Va.	1	199
Delaware & Hudson Company F. P. Gutelius, Vice-President, Albany, N. Y. C. S. Sims, Resident Vice-President, Montreal, Canada. J. B. Dickson, General Superintendent Transportation, Albany, N. Y. G. H. Burgess, Chairman, Valuation Committee, Albany, N. Y. James MacMartin, Chief Engineer, Albany, N. Y. F. D. Anthony, Construction Engineer, Albany, N. Y. John A. McGrew, Superintendent, Albany, N. Y.	7	916
Delaware, Lackawanna & Western Railroad G. J. Ray, Chief Engineer, Hoboken, N. J. R. M. White, Superintendent, Easton, Pa. A. E. Deal, Bridge Engineer, Hoboken, N. J. A. J. Neafie, Principal Assistant Engineer, Hoboken, N. J. G. E. Boyd, Division Engineer, Buffalo, N. Y. M. H. Doughty, Division Engineer, Hoboken, N. J. R. L. Dyke, Division Engineer, Elmira, N. Y. L. L. Tallyn, Division Engineer, Scranton, Pa. F. L. Wheaton, Division Engineer, Binghamton, N. Y. A. F. Colligan, Assistant Engineer, Scranton, Pa. D. R. Young, Assistant Engineer, Buffalo, N. Y. R. V. Glover, Transitman, Scranton, Pa.	12	996
Denver & Rio Grande Railroad H. U. Mudge, President, Denver, Colo. J. G. Gwyn, Chief Engineer, Denver, Colo. A. O. Ridgway, Assistant Chief Engineer, Denver, Colo.	3	2,901
Detroit Terminal Railroad C. E. Merwin, Chief Engineer, Detroit, Mich.	1	20
Dominion Atlantic Railway M. K. McQuarrie, Engineer, Kentville, Nova Scotia.	1	288
Duluth & Iron Range Railroad W. A. Clark, Chief Engineer, Duluth, Minn.	1	205
Duluth, Missabe & Northern Railroad W. A. McGonagle, President, Duluth, Minn. W. H. Hoyt, Assistant Chief Engineer, Duluth, Minn. F. C. Baluss, Engineer Bridges and Buildings, Duluth, Minn.	3	747
Duluth, South Shore & Atlantic Railway E. R. Lewis, Assistant to General Manager, Duluth, Minn. Nelson Cadarette, Assistant Engineer, Duluth, Minn.	2	747
Duluth, Winnipeg & Pacific Railway J. L. Pickles, Chief Engineer, West Duluth, Minn.	1	171
Elgin, Joliet & Eastern Railway A. Montzheimer, Chief Engineer, Joliet, Ill. F. H. Masters, Division Engineer, Gary, Ind.	2	447

Name of Road and Membership.	*Members.*	*Mileage.*
El Paso Southwestern System	2	1,027
J. L. Campbell, Engineer Maintenance of Way, El Paso, Texas.		
H. E. Stansbury, Resident Engineer, Tucumcari, N. M.		
Erie Railroad	23	2,522
F. D. Underwood, President, New York City.		
R. S. Parsons, Assistant to President, New York City.		
R. C. Falconer, Assistant Chief Engineer, New York City.		
C. H. Splitstone, Engineer of Construction, New York City.		
Harold Knight, Assistant Superintendent of Maintenance, New York City.		
W. W. Drinker, Principal Assistant Engineer, New York City.		
J. C. Patterson, Office Engineer, New York City.		
R. E. Woodruff, Superintendent, Youngstown, Ohio.		
Carl Bucholtz, Assistant Superintendent, Youngstown, Ohio.		
A. B. Caldwell, Trainmaster, Elmira, N. Y.		
O. F. Barnes, Division Engineer, Jersey City, N. J.		
R. H. Boykin, Division Engineer, Susquehanna, Pa.		
C. A. Daley, Division Engineer, Rochester, N. Y.		
W. P. Kimble, Division Engineer, Marion, Ohio.		
F. D. Lakin, Division Engineer, Meadville, Pa.		
C. M. Lewis, Division Engineer, Dunmore, Pa.		
I. H. Schram, Division Engineer, Youngstown, Ohio.		
J. R. Sexton, Division Engineer, Huntington, Ind.		
R. G. Wilson, Assistant Division Engineer, Jersey City, N. J.		
H. A. Lloyd, Special Agent, Jersey City, N. J.		
A. F. Trimble, Special Agent, New York City.		
W. M. Dawley, Assistant Engineer, New York City.		
C. A. Dayton, Assistant Engineer, Binghamton, N. Y.		
Ferrocarriles del Norte de Cuba	1	...
A. C. Spencer, Superintendent, Moron, Camaguey, Cuba.		
Florida East Coast Railway	1	745
R. H. Martin, Engineer Maintenance of Way, St. Augustine, Fla.		
C. S. Coe, Engineer Maintenance of Way, St. Augustine, Fla.		
Fonda, Johnstown & Gloversville Railway	1	110
F. A. Bagg, Chief Engineer, Gloversville, N. Y.		
Fort Dodge, Des Moines & Southern Railroad	1	124
C. E. Carson, Superintendent, Boone, Iowa.		
Fort Smith & Western Railroad	1	259
A. L. Mills, Receiver, Fort Smith, Ark.		
Fort Worth & Denver City Railway	2	454
H. A. Gausewitz, General Superintendent, Fort Worth, Texas.		
R. C. Gowdy, Chief Engineer, Fort Worth, Texas.		
Greater Winnipeg Water District Railway	1	...
W. R. Davis, Division Engineer, Winnipeg, Man., Canada.		
Georgia Railroad	1	307
W. M. Robinson, Roadmaster, Augusta, Ga.		

Name of Road and Membership. *Members.* *Mileage.*

Grand Trunk Railway System 30 4,790

Howard G. Kelley, Acting President, Montreal, Canada.
H. R. Safford, Chief Engineer, Montreal, Canada.
William McNab, Valuation Engineer, Montreal, Canada.
Arthur Crumpton, Assistant Valuation Engineer, Montreal, Canada.
M. S. Blaiklock, Engineer Maintenance of Way, Montreal, Canada.
H. B. Stuart, Structural Engineer, Montreal, Canada.
Robert Armour, Masonry Engineer, Montreal, Canada.
A. S. Going, Engineer Construction, Montreal, Canada.
U. E. Gillen, General Superintendent, Chicago, Ill.
Charles Forrester, Superintendent, Stratford, Ont., Canada.
F. C. L. Bond, Division Engineer, Montreal, Canada.
Ewert G. Hewson, Division Engineer, Toronto, Ont., Canada.
T. T. Irving, Division Engineer, Chicago, Ill.
Barton Wheelwright, Acting Signal Engineer, Montreal, Canada.
N. E. Baker, Supervisor of Signals, Battle Creek, Mich.
J. B. Gaut, Superintendent Bridges and Buildings, Chicago, Ill.
George A. Mitchell, Superintendent Bridges and Buildings, Toronto, Ont., Canada.
David McCooe, Superintendent of Track, Toronto, Ont., Canada.
J. H. Reagan, Superintendent of Track, Chicago, Ill.
A. R. Hannaford, Bridge Inspector, Toronto, Ont., Canada..
James Boyd, Assistant Engineer, Hamilton, Ont., Canada.
Francis H. McGuigan, Jr., Assistant Engineer, Montreal, Canada.
H. A. Palmer, Assistant Engineer, Toronto, Ont., Canada.
O. H. Sessions, Assistant Engineer, Battle Creek, Mich.
F. P. Sisson, Assistant Engineer, Detroit, Mich.
W. W. Smith, Assistant Engineer, Montreal, Canada.
L. I. Stone, Assistant Engineer, Toronto, Ont., Canada.
A. M. Blanchard, Valuation Department, Montreal, Canada.
G. Flora, Inspector of Track Valuation, Durand, Mich.
W. H. Rupp, Engineering Department, Montreal, Canada.

Grand Trunk Pacific Railway 4 2,748

W. H. Brewer, General Superintendent, Winnipeg, Man., Canada.
H. A. Woods, Assistant Chief Engineer, Winnipeg, Man., Canada.
Joseph N. DeStein, Resident Engineer, Rivers, Canada.
Sherman Smith, Assistant Engineer, Melville, Sask., Canada.

Great Eastern Railway of England 1 1,217

H. W. Thornton, General Manager, London, England.

Great Northern Railway.................................. 10 8,102

Ralph Budd, Assistant to President, St. Paul, Minn.
A. H. Hogeland, Chief Engineer, St. Paul, Minn.
J. R. W. Davis, Engineer Maintenance of Way, St. Paul, Minn.
J. A. Bohland, Bridge Engineer, St. Paul, Minn.
John C. Sesser, Superintendent, Superior, Wis.
C. M. Nye, Principal Assistant Engineer, St. Paul, Minn.

Name of Road and Membership.	*Members.*	*Mileage.*
Great Northern—Continued.		
Charles A. Dunham, Signal Engineer, St. Paul, Minn.		
R. S. Hubley, Office Engineer, Superior, Wis.		
D. J. Kerr, Office Engineer, St. Paul, Minn.		
H. F. Hamilton, Resident Engineer, St. Paul, Minn.		
Guatanamo Railway	1	...
Richard Brooks, General Manager and Chief Engineer, Guatanamo, Cuba.		
Gulf Lines Railway	1	110
H. Hatcher, Assistant to President, New York City.		
Gulf & Ship Island Railroad	1	307
W. H. Gardner, Jr., Chief Engineer, Gulfport, Miss.		
Hocking Valley Railway	3	351
M. J. Caples, Vice-President, Columbus, Ohio.		
William Michel, Chief Engineer, Columbus, Ohio.		
D. W. Smith, Valuation Engineer, Columbus, Ohio.		
Hudson Bay Railway	3	...
J. W. Porter, Chief Engineer, Winnipeg, Man., Canada.		
B. Henderson, Resident Engineer, The Pas, Man., Canada.		
L. E. Silcox, Division Engineer, The Pas, Man., Canada.		
Hudson & Manhattan Railroad	3	9
J. Vipond Davies, Vice-President and Director, New York City.		
H. W. Hudson, Engineer Foundations and Masonry, New York City.		
Geo. D. Snyder, Deputy Chief Engineer, New York City.		
Illinois Central Railroad	31	6,149
W. L. Park, Vice-President, Chicago, Ill.		
A. S. Baldwin, Chief Engineer, Chicago, Ill.		
A. E. Clift, General Superintendent, Chicago, Ill.		
L. A. Downs, General Superintendent, New Orleans, La.		
A. F. Blaess, Engineer Maintenance of Way, Chicago, Ill.		
W. G. Arn, Assistant Engineer Maintenance of Way, Chicago, Ill.		
F. L. Thompson, Assistant Chief Engineer, Chicago, Ill.		
D. J. Brumley, Valuation Engineer, Chicago, Ill.		
D. W. Thrower, Assistant Valuation Engineer, Chicago, Ill.		
J. M. Johnson, Consulting Engineer, Louisville, Ky.		
T. L. Dubbs, Superintendent, Greenville, Miss.		
J. M. Egan, Superintendent, Fulton, Ky.		
C. R. Knowles, Superintendent Water Service, Chicago, Ill.		
C. C. Westfall, Engineer of Bridges, Chicago, Ill.		
Charles Chandler, Assistant Engineer Bridges, Chicago, Ill.		
A. L. Davis, Office Engineer, Chicago, Ill.		
E. H. Bowser, Superintendent Timber Department, Memphis, Tenn.		
E. L. Crugar, District Engineer, New Orleans, La.		
W. M. Vandersluis, Signal Engineer, Chicago, Ill.		
C. G. Bryan, Valuation Department, Chicago, Ill.		
F. B. Oren, Roadmaster, Mattoon, Ill.		
J. L. Downs, Roadmaster, Memphis, Tenn.		
Thomas Quigley, Roadmaster, McComb, Miss.		
J. W. Welling, Roadmaster, Greenville, Miss.		
G. F. Arthur, Assistant Engineer, Chicago, Ill.		

Name of Road and Membership.	*Members.*	*Mileage.*
Illinois Central—Continued.		
W. P. Cronican, Assistant Engineer, Chicago, Ill.		
Maro Johnson, Assistant Engineer, Chicago, Ill.		
S. C. Jump, Assistant Engineer, Chicago, Ill.		
J. W. Moore, Assistant Engineer, Chicago, Ill.		
T. M. Pittman, Jr., Assistant Engineer, Chicago, Ill.		
L. O. Sloggett, Assistant Engineer, Chicago, Ill.		
Illinois Traction System	2	425
L. B. Martin, Engineer Maintenance of Way, Springfield, Ill.		
J. G. M. Leisenring, Signal Engineer, Springfield, Ill.		
Imperial Government Railways of Japan	9	...
Rioye Ono, Civil Engineer, Tokyo, Japan.		
S. Sugiura, Engineering Department, Tokyo, Japan.		
S. Kurokochi, Engineer, Tokyo, Japan.		
T. Ohmra, Engineer, Sapporo, Japan.		
J. Inagaki, Engineer, Genzan-Chosen, Japan.		
Tokichi Endo, Chief, Maintenance of Way and Works Section, Kobe, Japan.		
H. Inagaki, Tokyo, Japan.		
J. Yamaguchi, Maintenance of Way Department, Tokyo, Japan.		
Kikumatsu Hirai, Civil Engineer, Troy, N. Y.		
International & Great Northern Railroad	1	1,160
F. S. Schwinn, Assistant Superintendent, Palestine, Texas.		
Jay Street Terminal	1	...
L. D. Crear, Chief Engineer, Brooklyn, N. Y.		
Johnstown & Stony Creek Railroad	1	12
E. B. Entwisle, Chief Engineer, Johnstown, Pa.		
Kanawha & Michigan Railway	6	175
C. M. McVay, Engineer Maintenance of Way, Charleston, W. Va.		
Kansas City Southern Railway	6	865
C. E. Johnston, General Manager, Kansas City, Mo.		
J. M. Weir, Chief Engineer, Kansas City, Mo.		
C. S. Heritage, Bridge Engineer, Kansas City, Mo.		
A. F. Rust, Valuation Engineer, Kansas City, Mo.		
R. H. Gaines, Division Engineer, Texarkana, Texas.		
J. J. Taylor, Superintendent Bridges and Buildings, Texarkana, Texas.		
Kansas City Terminal Railway	2	76
John V. Hanna, Chief Engineer, Kansas City, Mo.		
G. E. Tebbetts, Bridge Engineer, Kansas City, Mo.		
Kentucky & Indiana Terminal Railroad	1	16
Chas. F. Burrell, Engineer Maintenance of Way, Louisville, Ky.		
Lake Shore Electric Railway	1	180
A. V. Brown, Engineer Maintenance of Way, Sandusky, Ohio.		
Lake Superior & Ishpeming, Munising, Marquette & Southeastern Railway	1	172
R. C. Young, Chief Engineer, Marquette, Mich.		
Lehigh & Hudson River Railroad	1	97
J. E. Barrett, Superintendent Track, Bridges and Buildings, Warwick, N. Y.		

Name of Road and Membership.	*Members.*	*Mileage.*
Lehigh & New England Railroad E. H. Shipman, Chief Engineer, South Bethlehem, Pa. C. W. Brown, Superintendent, South Bethlehem, Pa. F. W. Gilcreast, Engineer Maintenance, South Bethlehem, Pa.	3	296
Lehigh Valley Railroad G. T. Hand, Chief Engineer, New York City. E. B. Ashby, Consulting Engineer, New York City. G. L. Moore, Engineer Maintenance of Way, South Bethlehem, Pa. F. E. Schall, Bridge Engineer, South Bethlehem, Pa. W. C. Barrett, Division Engineer, Sayre, Pa. L. P. Rossiter, Division Engineer, Buffalo, N. Y.	6	1,442
Leopoldina Railway R. C. Crocker, Locomotive, Car and Marine Superintendent, Rio de Janiero, Brazil, S. A.	1	...
Little Kanawha Railroad S. D. Brady, Chief Engineer, Fairmont, W. Va.	1	30
Long Island Railroad J. R. Savage, Chief Engineer, Jamaica, N. Y. F. Auryansen, Bridge Engineer, Jamaica, N. Y. George Gibbs, Chief Engineer, Electric Traction, New York City.	3	397
Los Angeles & Salt Lake Railroad R. K. Brown, Engineer Maintenance, Los Angeles, Cal.	1	1,115
Louisiana & Arkansas Railway F. L. Beal, Chief Engineer, Stamps, Ark. E. J. Lassiter, Assistant Engineer, Stamps, Ark. T. E. White, Supervisor of Track, Minden, La.	3	283
Louisiana & Northwestern Railroad S. C. Stafford, Engineer, Homer, La.	1	121
Louisville & Nashville Railroad W. H. Courtenay, Chief Engineer, Louisville, Ky. R. Montfort, Consulting Engineer, Louisville, Ky. H. C. Williams, Chief Engineer Construction, Louisville, Ky. Charles H. Blackman, Principal Assistant Engineer, Louisville, Ky. J. F. Burns, Assistant Engineer Maintenance of Way, Louisville, Ky. G. W. Feagin, Locating Engineer, Louisville, Ky. J. S. Hestle, Roadmaster, Nashville, Tenn.	7	5,037
Maine Central Railroad G. F. Black, Engineer Maintenance of Way, Portland, Maine. W. H. Norris, Bridge Engineer, Portland, Maine.	2	1,347
Manila Railroad L. F. Goodale, Assistant to President, Manila, P. I.	1	...
Marinette, Tomahawk & Western Railroad R. B. Tweedy, President and Treasurer, Tomahawk, Wis.	1	20
Metropolitan Street Railway Company A. E. Harvey, Chief Engineer, Kansas City, Mo.	1	...
Midland Valley Railroad Charles Kaighn, Engineer Maintenance of Way, Muskogee, Okla.	1	364

Name of Road and Membership.	*Members.*	*Mileage.*
Minneapolis, St. Paul & Sault Ste. Marie Railway E. Pennington, President, Minneapolis, Minn. C. N. Kalk, Chief Engineer, Minneapolis, Minn. H. Pederson, Assistant Engineer, Minneapolis, Minn. B. T. Wherry, Assistant Engineer, St. Paul, Minn.	4	4,290
Minneapolis & St. Louis Railroad R. G. Kenly, General Manager, Minneapolis, Minn. J. H. Reinholdt, Chief Engineer, Minneapolis, Minn.	2	1,647
Minnesota, Dakota & Western Railroad Frank Birdsall, Superintendent, International Falls, Minn.	1	40
Mississippi Central Railroad L. E. Faulkner, Chief Engineer, Hattiesburg, Miss.	1	164
Mississippi River & Bonne Terre Railroad C. H. Fake, Engineer Maintenance of Way, Bonne Terre, Mo.	1	65
Missouri, Kansas & Texas Railway Frank Ringer, Chief Engineer, Dallas, Texas. L. F. Lonnbladh, Chief Engineer, Dallas, Texas. B. J. Dalton, Chairman, Valuation Committee, Parsons, Kan. S. B. Fisher, Engineering Department, Parsons, Kan. D. P. Pace, Division Engineer, Denison, Texas. A. M. Acheson, Superintendent, Trinity, Texas.	6	3,865
Missouri Pacific Railroad E. A. Hadley, Chief Engineer, St. Louis, Mo. H. R. Carpenter, Assistant Chief Engineer, St. Louis, Mo. A. F. Dorley, Engineer Maintenance of Way, Eastern District, St. Louis, Mo. J. R. Leighty, Engineer Maintenance of Way, Kansas City, Mo. R. C. White, Superintendent, Wynne, Ark. S. L. Wonson, Bridge Engineer, St. Louis, Mo. B. H. Mann, Signal Engineer, St. Louis, Mo. H. E. Billman, General Roadmaster, St. Louis, Mo. F. A. Jones, General Roadmaster, Wynne, Ark. O. Rickert, General Roadmaster, Monroe, La. J. A. Lahmer, Drainage Engineer, St. Louis, Mo. R. C. Bardwell, Assistant Engineer, St. Louis, Mo. W. J. Burton, Assistant Engineer, St. Louis, Mo. A. S. Butterworth, Assistant Engineer, St. Louis, Mo. J. S. Bassett, Assistant Engineer, Monroe, La. R. E. Warden, Assistant Engineer, Little Rock, Ark. C. A. Hewes, Assistant Engineer, Osawatomie, Kan. P. F. Gentine, Superintendent Bridges and Buildings, Pueblo, Colo.	18	7,298
Mobile & Ohio Railroad B. A. Wood, Chief Engineer, Mobile, Ala. H. Austill, Bridge Engineer, Mobile, Ala. Chas. A. Hayes, Architect, Mobile, Ala.	3	1,403
Monongahela Railroad D. K. Orr, Chief Engineer, Brownsville, Pa.	1	111
Monongahela Southern Railway H. L. Gordon, Engineer of Construction, Pittsburgh, Pa. R. S. Mitchell, Assistant Engineer Construction, Pittsburgh, Pa.	2	...
Montreal Tramways Company W. F. Graves, Chief Engineer, Montreal, Canada.	1	...

Name of Road and Membership.	*Members.*	*Mileage.*
Mount Royal Tunnel & Terminal Company	1	...
S. P. Brown, Chief Engineer, Montreal, Canada.		
Muskogee, Oklahoma & Gulf Railway	3	...
H. C. Ferris, Receiver, Muskogee, Okla.		
J. W. Dawson, Engineer Maintenance of Way, Muskogee, Okla.		
G. N. Toops, Engineer Maintenance of Way, Muskogee, Okla.		
Nashville, Chattanooga & St. Louis Railway	7	1,231
John Howe Peyton, President, Nashville, Tenn.		
Hunter McDonald, Chief Engineer, Nashville, Tenn.		
H. H. Trabue, Assistant Chief Engineer and Real Estate Agent, Nashville, Tenn.		
G. F. Blackie, Assistant Chief Engineer, Nashville, Tenn.		
E. D. Sloan, Valuation Engineer, Nashville, Tenn.		
G. D. Hicks, Superintendent, Tullahoma, Tenn.		
R. L. Schmid, Assistant Engineer, Chattanooga, Tenn.		
Newburgh & South Shore Railway	1	59
A. H. Stewart, Engineer Maintenance of Way, Cleveland, Ohio.		
New York Connecting Railroad	1	12
O. H. Ammann, Assistant Chief Engineer, New York City.		
New York Central Lines	83	12,161
New York Central Railroad, East of Buffalo.		
George W. Kittredge, Chief Engineer, New York City.		
A. T. Hardin, Vice-President, New York City.		
G. A. Harwood, Engineer Assistant to Vice-President in Charge of Operation, New York City.		
R. D. Starbuck, Engineer to Vice-President, New York City.		
Dr. P. H. Dudley, Consulting Engineer, New York City.		
E. B. Katte, Chief Engineer, Electric Traction, New York City.		
Geo. W. Vaughan, Engineer Maintenance of Way, New York City.		
Miles Bronson, Terminal Manager, New York City.		
H. S. Balliet, Assistant Terminal Manager and Signal Engineer, New York City.		
W. F. Jordan, Manager Grand Central Terminal Improvements, New York City.		
C. J. Coon, Engineer, Grand Central Terminal, New York City.		
J. W. Pfau, Engineer of Construction, New York City.		
H. T. Welty, Engineer of Structures, New York City.		
Z. H. Sikes, Assistant Engineer Structures, New York City.		
W. H. Elliott, Signal Engineer, Albany, N. Y.		
Chas. J. Parker, Principal Assistant Engineer, New York City.		
A. W. Carpenter, Assistant Valuation Engineer, New York City.		
D. L. Sommerville, Superintendent, Albany, N. Y.		
J. V. Neubert, Engineer of Track, New York City.		
Francis Boardman, Division Engineer, New York City.		
C. E. Lindsay, Division Engineer, Albany, N. Y.		
G. N. Edmondson, Division Engineer, Rochester, N. Y.		
B. M. McDonald, Division Engineer, Buffalo, N. Y.		
W. A. Murray, Division Engineer, Jersey Shore, Pa.		
Henry Lehn, Maintenance of Way Accountant, New York City.		
S. E. Coombs, Special Engineer, New York City.		
F. D. Bardwell, Special Assistant Engineer, New York City.		
H. M. Bassett, Special Assistant Engineer, New York City.		

Name of Road and Membership. *Members.* *Mileage.*

New York Central—Continued.

W. L. Morse, Special Assistant Engineer, New York City.
C. W. Beam, Assistant Engineer, Buffalo, N. Y.
H. E. Boardman, Assistant Engineer, New York City.
C. J. Graff, Assistant Engineer, New York City.
P. H. Spear, Assistant Engineer, New York City.

New York Central Railroad, West of Buffalo.

A. S. Ingalls, General Manager, Cleveland, Ohio.
C. G. Cleveland, Chief Engineer, Cleveland, Ohio.
Samuel Rockwell, Consulting Engineer, Cleveland, Ohio.
R. O. Rote, Assistant to Chief Engineer, Cleveland, Ohio.
B. R. Leffler, Engineer Bridges, Cleveland, Ohio.
Willard Beahan, First Assistant Engineer, Cleveland, Ohio.
J. H. Roach, Engineer in Charge of Valuation Work, Cleveland, Ohio.
G. D. Hill, Assistant Engineer, Valuation Department, Cleveland, Ohio.
Henry Stephens, Supervisor of Materials, Cleveland, Ohio.
C. B. Patterson, Engineering Department, Toledo, Ohio.

Pittsburgh & Lake Erie Railroad.

J. A. Atwood, Chief Engineer, Pittsburgh, Pa.
A. R. Raymer, Assistant Chief Engineer, Pittsburgh, Pa.
E. W. Boots, Assistant Engineer, Pittsburgh, Pa.
R. M. Pearce, Resident Engineer, Pittsburgh, Pa.
D. F. Harvey, Inspecting Engineer, Pittsburgh, Pa.
R. T. McMaster, Inspecting Engineer, Coraopolis, Pa.

Rutland Railroad.

John G. Shillinger, Chief Engineer, Rutland, Vt.

Toledo & Ohio Central Railroad.

J. A. Stocker, Chief Engineer, Columbus, Ohio.

Michigan Central Railroad.

G. H. Webb, Chief Engineer, Detroit, Mich.
J. F. Deimling, Assistant Chief Engineer, Detroit, Mich.
G. H. Harris, Engineer Maintenance of Way, Detroit, Mich.
Hans Ibsen, Bridge Engineer, Detroit, Mich.
G. C. Tuthill, Acting Bridge Engineer, Detroit, Mich.
J. C. Mock, Signal-Electrical Engineer, Detroit, Mich.
A. L. Sarvey, Valuation Engineer, Detroit, Mich.
W. H. Sellew, Valuation Department, Detroit, Mich.
A. M. Van Auken, Assistant Engineer Costs, Detroit, Mich.
J. D. Elder, Division Engineer, Niles, Mich.
John Evans, Division Engineer, Detroit, Mich.
J. E. Johnson, Division Engineer, St. Thomas, Ont., Canada.
T. H. Hickey, Inspector Maintenance of Way, Detroit, Mich.
A. T. Hopkins, Field Engineer, Detroit, Mich.

Cincinnati Northern Railroad.

W. D. Williams, Chief Engineer, Van Wert, Ohio.

Indiana Harbor Belt Railroad.

Otto Gersbach, Engineer Maintenance of Way, Gibson, Ind.

Name of Road and Membership. *Members.* *Mileage.*

New York Central—Continued.

Cleveland, Cincinnati, Chicago & St. Louis.

C. A. Paquette, Chief Engineer, Cincinnati, Ohio.
Hadley Baldwin, Assistant Chief Engineer, Cincinnati, Ohio.
O. E. Selby, Principal Assistant Engineer, Cincinnati, Ohio.
Paul Hamilton, Engineer Track and Roadway, Cincinnati, Ohio.
W. S. Burnett, Engineer Maintenance of Way, Springfield, Ohio.
W. C. Kegler, Engineer Maintenance of Way, Galion, Ohio.
J. E. Kissell, Engineer Maintenance of Way, Mt. Carmel, Ill.
A. F. Maischaider, Engineer Maintenance of Way, Mattoon, Ill.
C. W. Cochran, Engineer Maintenance of Way, Galion, Ohio.
A. M. Turner, District Engineer, Columbus, Ohio.
L. S. Rose, Engineer in Charge of Valuation Work, Cincinnati, Ohio.
Jos. Mullen, Special Engineer, Cincinnati, Ohio.
E. J. Bayer, Assistant Engineer Maintenance of Way, Galion, Ohio.
J. A. Nichols, Jr., Resident Engineer, Indianapolis, Ind.

Lake Erie & Western Railroad.

J. K. Conner, Chief Engineer, Indianapolis, Ind.
John F. Schwed, First Assistant Engineer, Indianapolis, Ind.

New York, Chicago & St. Louis Railroad 10 523

A. W. Johnston, Assistant to President, Cleveland, Ohio.
C. E. Denney, Special Engineer to President, Cleveland, Ohio.
E. E. Hart, Chief Engineer, Cleveland, Ohio.
W. J. Bergen, First Assistant to Chief Engineer, Cleveland, Ohio.
C. B. Hoyt, Superintendent Track, Maintenance and Construction, Cleveland, Ohio.
G. H. Tinker, Bridge Engineer, Cleveland, Ohio.
A. J. Himes, Valuation Engineer, Cleveland, Ohio.
Huntington Smith, Division Engineer, Cleveland, Ohio.
Willson Sprague, Division Engineer, Conneaut, Ohio.
J. W. Wilkinson, Division Engineer, Cleveland, Ohio.

New York, New Haven & Hartford Railroad............. 21 2,003

E. J. Pearson, President, Boston, Mass.
W. J. Backes, Engineer Maintenance of Way, New Haven, Conn.
C. D. Perkins, Assistant to Engineer Maintenance of Way, New Haven, Conn.
H. L. Ripley, Valuation Engineer, Boston, Mass.
Gilbert R. Kent, Principal Assistant Engineer Valuation, West Haven, Conn.
W. H. Moore, Engineer of Structures, New Haven, Conn.
H. E. Astley, Superintendent, Boston, Mass.
W. T. Spencer, Superintendent, Taunton, Mass.
Paul Sterling, Maintenance Engineer, Lines West, New Haven, Conn.
Walter D. Warren, Maintenance Engineer, Lines East, Boston, Mass.
F. H. Ellsworth, Division Engineer, New Haven, Conn.
J. W. Pearson, Division Engineer, Newton, Mass.
R. L. Pearson, Division Engineer, New London, Conn.
J. S. Ruff, Division Engineer, Waterbury, Conn.
H. A. Weaver, Division Engineer, Boston, Mass.

Name of Road and Membership.	*Members.*	*Mileage.*
New York, New Haven & Hartford—Continued.		
C. F. Yardley, Division Engineer, Hartford, Conn.		
Edwy L. Taylor, Contract Agent, New Haven, Conn.		
W. T. Dorrance, Chief Draftsman, New Haven, Conn.		
J. S. Browne, Assistant Engineer, New Haven, Conn.		
G. F. Hand, Assistant Engineer, New Haven, Conn.		
C. S. Flandreaux, Track Supervisor, Providence, R. I.		
New York, Ontario & Western Railroad................	4	568
J. H. Nuelle, General Superintendent, Middletown, N. Y.		
W. C. Heidenthal, Engineer Maintenance of Way, Middletown, N. Y.		
F. X. Soete, Valuation Engineer, Middletown, N. Y.		
Howard O'Connor, Roadmaster, Oneida, N. Y.		
New Zealand Railways	3	...
James Burnett, Chief Engineer, Wellington, N. Z.		
D. T. McIntosh, District Engineer, Auckland, N. Z.		
F. W. MacLean, Inspecting Engineer, Wellington, N. Z.		
Norfolk Southern Railroad	3	907
F. L. Nicholson, Chief Engineer, Norfolk, Va.		
John Archer, Resident Engineer, Norfolk, Va.		
H. S. Blake, Resident Engineer, Norfolk, Va.		
Norfolk & Western Railway............................	14	2,085
Chas. S. Churchill, Assistant to President, Roanoke, Va.		
J. E. Crawford, Chief Engineer, Roanoke, Va.		
W. R. Dawson, Assistant to General Manager, Roanoke, Va.		
W. J. Jenks, General Superintendent, Bluefield, W. Va.		
F. P. Turner, Bridge Engineer, Roanoke, Va.		
W. P. Wiltsee, Assistant to Chief Engineer, Roanoke, Va.		
J. R. Schick, Engineer Branch Lines, Roanoke, Va.		
D. W. Richards, Signal Engineer, Roanoke, Va.		
J. H. Gibboney, Chief Chemist, Roanoke, Va.		
A. Bruner, Assistant Engineer, Roanoke, Va.		
J. A. Davenport, Assistant Engineer, Roanoke, Va.		
C. F. Losh, Assistant Engineer, Roanoke, Va.		
R. M. Miller, Assistant Engineer, Norfolk, Va.		
O. V. Parsons, Chief Draftsman, Roanoke, Va.		
Northern Pacific Railway	14	6,727
A. M. Burt, Chief Engineer Maintenance of Way, St. Paul, Minn.		
L. M. Perkins, Engineer Maintenance of Way, Tacoma, Wash.		
Louis Yager, Engineer Maintenance of Way, St. Paul, Minn.		
C. A. Christofferson, Signal Engineer, St. Paul, Minn.		
H. M. Stout, Record Engineer, St. Paul, Minn.		
Bernard Blum, Division Engineer, St. Paul, Minn.		
J. D. Koren, Division Engineer, Spokane, Wash.		
Lowry Smith, Special Engineer, Brainerd, Minn.		
R. T. Taylor, Trainmaster, Duluth, Minn.		
G. A. Kenrick, Assistant Engineer, Spokane, Wash.		
F. J. Challoner, Roadmaster, Dilworth, Minn.		
C. W. Fee, Roadmaster, Tacoma, Wash.		
E. H. Brown, Supervisor Bridges and Buildings, Minneapolis, Minn.		
E. M. Grime, Supervisor Bridges and Buildings, Dilworth, Minn.		
Northern Railway Company	1	...
M. M. Marsh, Superintendent Way and Bridges, Siquirres, Costa Rica, C. A.		
Oahu Railway & Land Company	1	...
C. B. Andrews, Chief Engineer, Honolulu, Hawaii.		

Name of Road and Membership.	*Members.*	*Mileage.*
Pennsylvania Lines West of Pittsburgh	27	4,025
D. F. Crawford, General Manager, Pittsburgh, Pa.		
Thos. Rodd, Chief Engineer, Pittsburgh, Pa.		
W. C. Cushing, Chief Engineer Maintenance of Way, Southwest System, Pittsburgh, Pa.		
F. T. Hatch, Chief Engineer Maintenance of Way, St. Louis System, St. Louis, Mo.		
Robert Trimble, Chief Engineer Maintenance of Way, Northwest System, Pittsburgh, Pa.		
J. C. Bland, Engineer of Bridges, Pittsburgh, Pa.		
R. C. Barnard, Superintendent, Cincinnati, Ohio.		
Paul Jones, Superintendent, Toledo, Ohio.		
R. K. Rochester, Superintendent, Cleveland, Ohio.		
F. J. Stimson, Superintendent, Richmond, Ind.		
Maurice Coburn, Principal Assistant Engineer, St. Louis, Mo.		
E. G. Ericson, Principal Assistant Engineer, Pittsburgh, Pa.		
W. R. Hillary, Supervising Engineer, Toledo, Ohio.		
A. A. Wirth, Supervising Engineer, Pittsburgh, Pa.		
W. D. Wiggins, Valuation Engineer, Pittsburgh, Pa.		
Z. M. Briggs, Engineer, Pittsburgh, Pa.		
C. S. Davis, Structural Engineer, Detroit, Mich.		
G. R. Barry, Division Engineer, Columbus, Ohio.		
D. P. Beach, Division Engineer, Indianapolis, Ind.		
F. N. Crowell, Division Engineer, Cincinnati, Ohio.		
D. B. Johnston, Division Engineer, Louisville, Ky.		
Guy Scott, Division Engineer, Fort Wayne, Ind.		
E. B. Taylor, Jr., Division Engineer, Pittsburgh, Pa.		
H. W. Brown, Assistant Division Engineer, Chicago, Ill.		
T. L. Doyle, Assistant Division Engineer, Logansport, Ind.		
J. L. Taylor, Jr., Assistant Division Engineer, Pittsburgh, Pa.		
H. T. Sympson, Assistant Engineer, Terre Haute, Ind.		
Pennsylvania Railroad	16	5,388
J. G. Rodgers, General Superintendent, Buffalo, N. Y.		
A. W. Gibbs, Chief Mechanical Engineer, Philadelphia, Pa.		
H. C. Booz, Assistant Chief Engineer, Philadelphia, Pa.		
E. B. Temple, Assistant Chief Engineer, Philadelphia, Pa.		
J. F. Murray, Assistant to Chief Engineer, Philadelphia, Pa.		
G. R. Sinnickson, Superintendent, Baltimore, Md.		
A. H. Rudd, Signal Engineer, Philadelphia, Pa.		
G. W. Snyder, Principal Assistant Engineer, Pittsburgh, Pa.		
W. H. Cookman, Architect, Philadelphia, Pa.		
Robert Bell, Special Agent, Buffalo, N. Y.		
W. A. Moncure, Assistant Real Estate Agent, Philadelphia, Pa.		
W. S. Thompson, Division Engineer, Sunbury, Pa.		
C. W. Richey, Master Carpenter, Pittsburgh, Pa.		
C. H. Niemeyer, Assistant Engineer Maintenance of Way, Philadelphia, Pa.		
P. S. Lewis, Supervisor, Philadelphia, Pa.		
H. H. Groves, Transitman, East Aurora, N. Y.		
Pere Marquette Railroad	7	2,247
F. H. Alfred, President and General Manager, Detroit, Mich.		
A. L. Grandy, Assistant General Manager, Detroit, Mich.		
Job Tuthill, Chief Engineer, Detroit, Mich.		
H. A. Cassil, Engineer Maintenance of Way, Detroit, Mich.		
C. S. Sheldon, Engineer Bridges and Structures, Detroit, Mich.		
A. R. Dewees, Division Engineer, Saginaw, Mich.		
C. N. Quigley, Assistant Engineer, Detroit, Mich.		
Peoria & Pekin Union Railway	1	20
A. J. Wharf, Chief Engineer, Peoria, Ill.		

Name of Road and Membership.	*Members.*	*Mileage.*
Philadelphia & Reading Railway C. H. Ewing, General Manager, Philadelphia, Pa. J. E. Turk, Assistant to General Manager, Reading, Pa. S. T. Wagner, Chief Engineer, Philadelphia, Pa. F. S. Stevens, Engineer Maintenance of Way, Reading, Pa. R. B. Abbott, Superintendent, Harrisburg, Pa. Clark Dillenbeck, Engineer Bridges and Buildings, Philadelphia, Pa. C. M. Taylor, Superintendent, Creosoting Plants, Port Reading, N. J. P. S. Lewis, Passenger Trainmaster, Reading, Pa.	8	1,608
Philadelphia, Bethlehem & New England Railroad S. C. Ondarcho, Supervisor of Track, Bethlehem, Pa.	1	57
Philippine Islands Railway R. R. Hancock, Vice-President and General Manager, Iloilo, P. I.	1	...
Pittsburgh & West Virginia Railway W. F. Purdy, Chief Engineer, Pittsburgh, Pa. C. A. Stelle, Assistant Engineer, Pittsburgh, Pa.	2	63
Pittsburg, Shawmut & Northern Railway H. S. Wilgus, Engineer Maintenance of Way, Angelica, N. Y.	1	204
Pittsburg & Shawmut Railway W. W. Morrison, Engineer Maintenance of Way, Kittanning, Pa.	1	96
Potosi Sucre Railway W. L. Miller, Chief Engineer, Potosi, Bolivia, S. A.	1	...
Public Service Railway Martin Schreiber, Chief Engineer, Newark, N. J.	1	809
Richmond, Fredericksburg & Potomac Railway S. B. Rice, Engineer Maintenance of Way, Richmond, Va. E. M. Hastings, Resident Engineer, Richmond, Va. J. D. Mason, General Foreman Bridges and Buildings, Fredericksburg, Va.	3	124
Richmond Terminal Railway C. C. Strong, Resident Engineer, Richmond, Va.	1	...
Rio Grande & Eagle Pass Railway R. W. Davis, Engineer Maintenance of Way and Construction, Dolores, Texas.	1	28
St. Joseph & Grand Island Railway W. A. Parker, Chief Engineer, St. Joseph, Mo.	1	258
St. Louis, Brownsville & Mexico Railway C. S. Kirkpatrick, Division Engineer, Kingsville, Texas.	1	528
St. Louis, Iron Mountain & Southern Railway. (See Missouri Pacific Railroad.)		

Name of Road and Membership.	*Members.*	*Mileage.*
St. Louis-San Francisco Railroad F. G. Jonah, Chief Engineer, St. Louis, Mo. V. K. Hendricks, Assistant Chief Engineer, St. Louis, Mo. H. B. Barry, District Engineer, Memphis, Tenn. J. M. Sills, District Engineer, Springfield, Mo. F. P. Swartz, District Engineer, Springfield, Mo. O. C. Steinmayer, Supervisor Timber Preservation, Springfield, Mo. E. C. Baity, Assistant Engineer, Springfield, Mo.	7	4,769
St. Louis Southwestern Railway F. W. Green, Assistant to Vice-President, St. Louis, Mo. C. D. Purdon, Chief Engineer, St. Louis, Mo. E. L. Markham, Division Engineer, Pine Bluff, Ark. D. B. Cutler, Pilot Engineer, Tyler, Texas.	8	1,685
St. Louis Southwestern Railway of Texas. W. T. Eaton, Chief Engineer, Tyler, Texas. L. H. Lacy, care Chief Engineer, Tyler, Texas. W. H. Vance, Engineer Maintenance of Way, Tyler, Texas. S. J. Buckalew, Valuation Engineer, St. Louis, Mo.		
St. Louis, Troy & Eastern Railroad F. J. Reinke, Assistant Chief Engineer, St. Louis, Mo.	1	27
San Francisco-Oakland Terminal Railways A. W. Macpherson, Acting Chief Engineer, Oakland, Cal.	1	257
San Antonio & Aransas Pass Railway John S. Peter, Vice-President and General Manager, San Antonio, Texas. F. W. Bailey, Superintendent Maintenance of Way, Yoakum, Texas.	2	724
Southern New England Railroad R. D. Garner, Engineer Construction, Providence, R. I. Albert Larsen, Resident Engineer, Providence, R. I. A. S. Lyon, Resident Engineer, Southbridge, Mass.	3	78
South Manchurian Railway Naonobu Tani, Principal Assistant Engineer, Darien, Manchuria, China. Y. Maruyama, Engineering Department, Darien, China.	2	...
Seaboard Air Line Railway W. J. Harahan, President, Norfolk, Va. W. L. Seddon, Assistant to President, Norfolk, Va. L. C. Fritch, General Manager, Norfolk, Va. W. D. Faucette, Chief Engineer, Norfolk, Va. E. W. Smith, Assistant to Chief Engineer, Norfolk, Va. E. A. Frink, Principal Assistant Engineer, Norfolk, Va. J. C. Nelson, Engineer Maintenance of Way, Norfolk, Va. Guy Pinner, Bridge Engineer, Norfolk, Va. W. L. Darden, Engineer Buildings, Norfolk, Va. J. T. Elmore, Division Engineer, Richmond, Va. M. H. Gold, Division Engineer, Savannah, Ga. W. J. Gooding, Division Engineer, Jacksonville, Fla. J. L. Kirby, Division Engineer, Hamlet, N. C. A. O. Wilson, Division Engineer, Charleston, S. C. L. A. Murr, Assistant Engineer, Portsmouth, Va.	19	3,449

Name of Road, and Membership. *Members.* *Mileage.*

Seaboard Air Line—Continued.

R. H. Garrett, Assistant Engineer, Valuation Department, Norfolk, Va.
D. M. McKey, Locating Engineer, Plant City, Fla.
J. B. McClain, Assistant Bridge Engineer, Cedartown, Ga.
W. C. Cathey, Bridge Inspector, Norfolk, Va.

Southern Railway 21 7,940

H. B. Spencer, Vice-President, Washington, D. C.
T. H. Gatlin, Assistant to Vice-President, Washington, D. C.
B. Herman, Chief Engineer Maintenance of Way and Structures, Charlotte, N. C.
J. S. Lemond, Assistant to Chief Engineer of Maintenance of Way and Structures, Charlotte, N. C.
D. W. Lum, Special Engineer, Washington, D. C.
W. J. Eck, Signal and Electrical Engineer, Washington, D. C.
H. N. Rodenbaugh, Principal Assistant Engineer, Washington, D. C.
W. F. H. Finke, Tie and Timber Agent, Washington, D. C.
T. G. Townsend, Timber Treating Inspector, Washington, D. C.
J. C. Ramage, Superintendent of Tests, Alexandria, Va.
C. A. Redinger, Resident Engineer, Selma, N. C.

Western Lines.

Horace Baker, General Manager, Cincinnati, Ohio.
Curtis Dougherty, Chief Engineer, Cincinnati, Ohio.
A. A. Woods, Superintendent, New Orleans, La.
M. J. Connerton, Engineer Maintenance of Way, Chattanooga, Tenn.
G. H. Gilbert, Engineer Bridges and Buildings, Cincinnati, Ohio.
Adam Ritter, Architect, Cincinnati, Ohio.
W. F. McDade, Division Engineer, Columbus, Miss.
J. F. Whiteside, Roadmaster, Danville, Ky.
A. W. Owen, Assistant Engineer, Cincinnati, Ohio.
George Story, Jr., Assistant Engineer, Cincinnati, Ohio.

Southern Pacific System.................................. 35 11,943

Julius Kruttschnitt, Chairman Executive Committee, New York City.
John D. Isaacs, Consulting Engineer, New York City.
W. C. Barnes, Assistant Consulting Engineer, New York City.

Southern Pacific Company.

William Hood, Chief Engineer, San Francisco, Cal.
J. Q. Barlow, Assistant Chief Engineer, San Francisco, Cal.
A. T. Mercier, Assistant Superintendent, Dunsmuir, Cal.
O. Weeks, Assistant Superintendent, Ogden, Utah.
G. W. Corrigan, Division Engineer, Stockton, Cal.
W. M. Jaekle, Division Engineer, Los Angeles, Cal.
W. H. Kirkbride, Division Engineer, Sacramento, Cal.
E. C. Morrison, Division Engineer, San Francisco, Cal.
A. W. Perrin, Division Engineer, Alameda, Cal.
D. A. Porter, Division Engineer, Oakland, Cal.
F. M. Siefer, Division Engineer, Portland, Ore.
C. A. Wester, Division Engineer, Dunsmuir, Cal.
R. M. Drake, Maintenance of Way Assistant, San Francisco, Cal.
H. B. Titcomb, Maintenance of Way Assistant, San Francisco, Cal.

Name of Road and Membership.	*Members.*	*Mileage.*
Southern Pacific—Continued.		
Southern Pacific Lines in Texas and Louisiana.		
W. B. Scott, President, Houston, Texas.		
G. S. Waid, Vice-President and General Manager, Houston, Texas.		
E. B. Cushing, Assistant General Manager, Houston, Texas.		
R. Jones, Superintendent, Victoria, Texas.		
C. R. Morrill, Superintendent, Austin, Texas.		
R. C. Watkins, Superintendent, San Antonio, Texas.		
Harry Slabotsky, Assistant Superintendent, Lafayette, La.		
C. M. Staples, Assistant Superintendent, Ennis, Texas.		
I. A. Cottingham, Special Engineer Valuation, Houston, Texas.		
E. E. Worthing, Signal Engineer, Houston, Texas.		
W. W. Kelly, Division Engineer, Winslow, Ariz.		
J. D. Mathews, Division Engineer, Tucson, Ariz.		
T. M. Hutson, Roadmaster, Victoria, Texas.		
F. L. Guy, Resident Engineer, Douglas, Ariz.		
Lewis Mims, Fuel and Timber Agent, Houston, Texas.		
M. C. Shibley, Engineering Department, Lafayette, La.		
Southern Pacific Lines in Mexico.		
E. B. Sloan, Assistant Superintendent, Sinaloa, Mazatlan, Mexico.		
C. E. Cate, Engineer Maintenance of Way, Empalme, Sonora, Mexico.		
Spokane International Railway	1	163
E. G. Taber, Chief Engineer, Spokane, Wash.		
Spokane, Portland & Seattle Railway	1	556
W. E. Burkhalter, Office Engineer, Portland, Oregon.		
Susquehanna & New York Railroad	1	103
C. A. Derr, Engineer, Williamsport, Pa.		
Tehuantepec National Railway	1	188
F. W. Blake, General Manager, Rincon Antonio, Oaxaca, Mexico.		
Temiskaming & Northern Ontario Railway	1	330
S. B. Clement, Chief Engineer, North Bay, Ont., Can.		
Terminal Railroad Association of St. Louis	2	12
H. J. Pfeifer, Engineer Maintenance of Way, St. Louis, Mo.		
J. F. Peters, Assistant Engineer, St. Louis, Mo.		
Texas Midland Railway	1	125
L. W. Wells, Assistant to General Manager and Chief Engineer, Terrell, Texas.		
Texas & Pacific Railway	6	1,944
S. D. Bacon, Division Engineer, Marshall, Texas.		
F. W. Bettle, Division Engineer, Big Spring, Texas.		
V. R. Irvine, Cost Engineer Valuation, Dallas, Texas.		
R. L. Holmes, Assistant Engineer, Dallas, Texas.		
R. J. Gammie, Assistant Engineer, Dallas, Texas.		
E. M Wood, Draftsman, Dallas, Texas.		
Toledo, St. Louis & Western Railroad	1	451
F. R. Ramsey, Chief Engineer, Frankfort, Ind.		
Toledo & Western Railway	2	81
F. R. Coates, President, Toledo, Ohio.		
Albert Swartz, Vice-President, Sylvania, Ohio.		

Name of Road and Membership.	*Members.*	*Mileage.*
Toronto, Hamilton & Buffalo Railway	1	101
R. L. Latham, Chief Engineer, Hamilton, Ont., Can.		
Toronto Terminals Railway	2	...
J. R. W. Ambrose, Chief Engineer, Toronto, Canada. Harald Steenbuch, Structural Engineer, Toronto, Ont., Canada.		
Transcontinental Railway	2	1,800
Gordon Grant, Chief Engineer, Ottawa, Canada. W. A. Cowan, Assistant General Superintendent, Cochrane, Ont., Canada.		
Trinity & Brazos Valley Railroad	1	345
Springfield Baldwin, Valuation Engineer, Teague, Tex.		
Twin City Rapid Transit Company	1	...
G. L. Wilson, Engineer Maintenance of Way, Minneapolis, Minn.		
Unitah Railway	1	68
M. W. Cooley, General Manager, Mack, Colo.		
Union Pacific System	14	7,981
Union Pacific Railroad.		
R. L. Huntley, Chief Engineer (Assistant General Manager), Omaha, Neb. E. E. Adams, Consulting Engineer, New York City. N. F. Harriman, Chemist and Engineer of Tests, Omaha, Neb. F. W. Pflegíng, Signal Engineer, Omaha, Neb. A. C. Everham, Terminal Engineer, Kansas City, Mo. E. R. Houghton, Assistant Engineer, Omaha, Neb. C. C. Post, Jr., Assistant Engineer, Omaha, Neb. R. R. Paine, Assistant Engineer, Omaha, Neb. W. H. Hulsizer, Assistant Engineer, Valuation Department, Omaha, Neb.		
Oregon Short Line	1	2,259
Carl Stradley, Chief Engineer, Salt Lake City, Utah.		
Oregon-Washington Railroad & Navigation Company	4	2,027
Oliver Owre, Assistant Engineer Construction, Portland, Ore. S. B. Phillips, Assistant Engineer, Portland, Ore. W. C. Taylor, Assistant Engineer, Portland, Ore. R. Koehler, Portland, Ore.		
United Railways & Electric Company	1	...
W. W. Wysor, Assistant Chief Engineer, Baltimore, Md.		
United Traction Company of Indiana	1	...
L. A. Mitchell, Superintendent, Anderson, Ind.		
Utah Light, Railway & Power Company	1	48
L. L. Dagron, Engineer, Salt Lake City, Utah.		
Victorian Government Railways	1	...
Chas. E. Norman, Commissioner, Melbourne, Australia.		
Virginia-Carolina Railroad	1	79
G. P. Johnson, President, Abingdon, Va.		

Name of Road and Membership.	*Members.*	*Mileage.*
Virginian Railroad C. W. Huntington, Chairman Directorate, New York City. H. Fernstrom, Chief Engineer, Norfolk, Va. F. F. Harrington, Engineer Structures, Norfolk, Va. A. M. Traugott, Division Engineer, Princeton, W. Va. F. W. Hawks, Valuation Engineer, Norfolk, Va.	5	474
Wabash Railway J. E. Taussig, Assistant to President, St. Louis, Mo. H. A. Osgood, Assistant to Vice-President, St. Louis, Mo. A. O. Cunningham, Chief Engineer, St. Louis, Mo. R. H. Howard, Chief Engineer Maintenance of Way, St. Louis, Mo. Walt Dennis, Principal Assistant Engineer, St. Louis, Mo. W. S. Danes, Engineer Maintenace of Way, Peru, Ind. Noah Johnson, Engineer Maintenance of Way, Peru, Ind. W. K. Walker, Engineer Maintenance of Way, Montpelier, Ohio.	8	2,510
Washington Terminal Company C. S. Heritage, Engineer, Washington, D. C.	1	52
Watauga & Yadkin River Railroad H. C. Landon, General Manager, North Wilkesboro, N. C.	1	31
Waterloo, Cedar Falls & Northern Railway T. E. Rust, Chief Engineer, Waterloo, Iowa.	1	135
Western & Atlantic Railroad I. O. Walker, Division Engineer, Atlanta, Ga.	1	...
Western Maryland Railroad M. C. Byers, Assistant to President, Baltimore, Md. G. H. Friend, Division Engineer, Hagerstown, Ind.	2	773
Wheeling & Lake Erie Railroad W. L. Rohbock, Chief Engineer, Cleveland, Ohio. R. J. McComb, Superintendent of Track, Brewster, Ohio. S. S. Senter, Superintendent Bridges and Buildings, Brewster, Ohio. D. M. Taylor, Assistant Engineer, Cleveland, Ohio.	4	459
Winchester & Virginia Railroad W. McC. Bond, Superintendent Construction, Winchester, Va.	1	...
Total mileage		266,978

American Railway Engineering Association

VOL. 19, No. 196 JUNE, 1917

THE EIGHTEENTH ANNUAL CONVENTION.

The Eighteenth Annual Convention of the American Railway Engineering Association convened in the Florentine Room of the Congress Hotel, Chicago, March 20, 21 and 22, 1917.

The business before the meeting consisted of the reading of the President's Address, the reports of the Secretary and of the Treasurer, and of the Standing and Special Committees, as follows: Roadway, Ballast, Ties, Rail, Track, Buildings, Wooden Bridges and Trestles, Masonry, Signs, Fences and Crossings, Signals and Interlocking, Records and Accounts, Rules and Organization, Water Service, Yards and Terminals, Iron and Steel Structures, Wood Preservation, Conservation of Natural Resources, Uniform General Contract Forms, Grading of Lumber and Stresses in Railroad Track.

The annual dinner was given on the evening of March 21, in the Gold Room of the Congress Hotel, and the spirit of good-fellowship was gratifying. Addresses were made by Sir William Peterson, Dean W. H. Thornton and Samuel O. Dunn.

The election of officers resulted as follows:

President, John G. Sullivan.

Vice-President, Earl Stimson.

Treasurer, Geo. H. Bremner.

Secretary, E. H. Fritch.

Three Directors, J. A. Atwood, W. H. Courtenay, E. A. Downs.

Members of Nominating Committee, J. R. W. Ambrose, Geo. H. Burgess, V. K. Hendricks, W. M. Dawley and Samuel T. Wagner.

On Friday, March 23, the members and guests made an inspection trip to the Gary Steel Works, the American Bridge Company's plant at Gary and the plant of the Universal Portland Cement Company at Buffington, Ill.

OBITUARY.

James Burke, Superintendent of the Chicago Terminal, Erie Railroad, died at his home in Chicago on April 17. Mr. Burke entered railway service on the Chicago, Milwaukee & St. Paul Railway in 1873, and was subsequently in the Engineering Department on the Chicago Northwestern, work train conductor and Assistant Roadmaster on the Atchison, Topeka & Santa Fe Railway, and Roadmaster on the Minneapolis & St. Louis Railroad. Mr. Burke then entered the service of the Minneapolis, St. Paul & Sault Ste. Marie as Superintendent of Construction and was promoted to General Roadmaster of the same lines. In 1899 he was made Division Engineer of the Baltimore & Ohio Railroad and in 1902 was made Engineer Maintenance of Way of the Erie Railroad with office at Cleveland, Ohio. Subsequently he was appointed Superintendent of Roadway, Bridges and Buildings, and in the early part of 1914 was appointed Superintendent of Terminals with headquarters at Chicago.

Mr. Burke was an active member of the American Railway Engineering Association, identifying himself with the organization in March, 1904.

WRITTEN DISCUSSION OF COMMITTEE REPORTS AND MONOGRAPHS.

The Board of Direction desires to call the attention of members to the desirability of written discussions of committee reports and monographs. Members who are unable to attend the annual convention or to take part in committee work are requested to make use of this medium for expressing their views and contribute to the common fund of knowledge.

Written discussions add to the interest of the reports and make available ideas and experiences that otherwise might not be accessible to the members.

Discussions in writing, upon their receipt, will be first transmitted to the chairmen of committees or authors of monographs, to afford an opportunity of commenting thereon.

TRANSLATION OF GENERAL SPECIFICATIONS FOR STEEL RAILWAY BRIDGES INTO THE SPANISH LANGUAGE.

The General Specifications for Steel Railway Bridges formulated by the Committee on Iron and Steel Structures, and forming part of the Manual of the American Railway Engineering Association, have been translated into the Spanish language and published under the auspices of the Argentine Republic Government for the information of engineers in South American countries. The introductory to the translation states that the specifications referred to exemplify the best modern practice for steel railway bridges.

BOOK REVIEWS.

DESIGN OF RAILWAY LOCATION, by C. C. WILLIAMS; John Wiley & Sons, Inc., New York, $3.50.

In the preface, the author of the book under review has clearly laid down the principles which the text of the book is to be based on, and has throughout the work followed out in logical order this prefatory statement.

These principles are as follows:

(1) That the work is intended for use as a text book in classes in technical schools as well as to be of value to engineers engaged in practical railroad work.

(2) The work is to explain and develop underlying principles rather than current practice.

(3) Much consideration is to be given to the fact that changes in traffic and operating conditions have made necessary the revision and relocation of already existing lines.

(4) There is to be kept before the student and reader the relation of fixed charges, governed by the location, to the expense of operation.

The text of the book, outside of the preface and index, is divided into four parts with an appendix.

Part A.—Railway Economics and Legislation, outlines the nature of a railway corporation from the point of the granting of the charter up to and including an analysis of railway rates and revenues. Also included in this part is a chapter on the Classification of Operating Expenses as laid down by the Interstate Commerce Commission, and in this chapter, while the author's descriptive matter is taken from the Commission's issue of 1914, the table accompanying is based on the old classification.

As a general proposition it is dangerous to make general references to the legal phases of railway organizations, inasmuch as the law differs so greatly in individual states. There is a question whether some of the statements made by the author might not be questioned in certain of the states.

Part B.—Operating Conditions Affecting Location. The first chapter takes up the characteristics of the steam locomotive; the latter part of the chapter ending with that important part connected with such locomotive, namely, its tractive effort. There are also chapters on electric traction, such rolling stock as freight cars, train resistance, train operation, ruling, momentum and minor grades, assistant engines, distance and curvature. With regard to this Part B, bearing in mind that the book is for use in technical schools, more space could profitably be devoted to explaining the action of brick arches and the effect of superheating steam. Under Electric Traction, more attention could profitably be paid to outlining facts upon which could be based a conclusion as to whether it is more economical to provide electric traction or to reduce grade on existing lines.

Part C.—Special Problems in Railway Location. This part analyzes in a thorough manner the changes which may be found necessary to make in an existing line to meet new conditions by line changes, grade reduction, electrification, elimination of grade-crossings, additional tracks, etc. It also has a chapter on the location of electric interurban railways. As mentioned above, it is unfortunate that the author in this part also has not gone as thoroughly into the subject of electrification as he has into others.

Part D.—Practical Location Surveys. This covers the detailed directions for gathering in the field the necessary data, the analysis of this data when obtained and the conclusions as to the economic location under certain necessary assumptions.

The reader will undoubtedly question individual statements or paragraphs in the book; but taken as a whole the work is well put together, the English good, the figures are close to the explanatory text, making it easy reading, and throughout there is kept before the reader the essential balance between annual cost, including fixed charge, and operating expenses.

THE WORLD'S GREAT ARCHES.

Reviewed by D. B. Steinman, C.E., Ph.D., Associate Engineer, Waddell & Son, New York.

GRANDES VOUTES.

By M. Paul Sejourne, Ingenieur en Chef des Ponts et Chaussees.

What is probably the most monumental engineering treatise in any language has just been published in Paris. This work, on "Great Stone and Concrete Arches," by Monsieur Paul Sejourne, is issued in six quarto volumes, contains 1,230 halftones and other illustrations, and includes a wealth of tabulated and descriptive data on the great arch bridges of the world. The price of 250 francs (about $50) is well warranted by the value of the volumes in contents and in make-up. The publication is a splendid example of how engineering books can and should be produced, and should prove an inspiration to other publishers and authors.

The books are published by Messrs. Tardy-Pigelet et Fils of Bourges. They are printed on unusually heavy paper (the six volumes weigh 25 pounds), and the typography and cuts are of a character unequaled in American technical literature. The general arrangement is admirably conceived, with fine halftone photographs and clear line-cut construction drawings of each structure disposed on facing pages in a convenient and instructive manner.

The entire work has evidently been a labor of love on the part of its author. This renowned French engineer must have devoted many years to the selection and preparation of the material contained in these volumes. Above an adopted minimum span-length of 40 meters (131 feet), practically every stone or concrete arch of any note has been included. Although French examples naturally predominate, the great structures of America, England, Germany, Switzerland, Austria, Norway, Italy, and other countries are represented. Monsieur Sejourne, in the course of his brilliant professional career, has had exceptional opportunities to accumulate this wealth of information, and has earned the grateful appreciation of his colleagues all over the world for rendering this material available to the entire profession.

The chief value of the books will be found in their many beautiful illustrations. For the more important structures, several photographs are given to show the architectural effect from different aspects and to emphasize various striking features of the designs in a highly instructive and impressive manner.

In masonry and concrete arches, more than in most other types of engineering construction, the designer is largely dependent upon precedent in order to secure the best results of structural efficiency and æsthetic conception. For this reason, Sejourne's illustrations will be found invaluable to designers of arch bridges as a supplement to the more strictly mathematical works in this field.

The six volumes of "Grandes Voutes" ought to find a place in every large public library as a work of reference for architects and engineers. Even for those who cannot read the French text, the photographs and drawings will be instructive and inspiring. The books should also be placed in every technical school for the benefit of engineering students.

The regular use of these volumes by bridge specialists and students in structural engineering would soon improve materially the status of the designing of reinforced concrete structures and would be an inspiration to the higher artistic conception of our public engineering works.

DONATIONS TO LIBRARY.

THE DESIGN OF RAILWAY LOCATION, by C. C. Williams, Professor of Railway Engineering, University of Kansas; John Wiley & Sons, New York. Cloth, $3.50.

JOHN FRITZ MEDAL BOOK, issued by the John Fritz Medal Board of Award, New York City.

FOUR TUNNELS IN THE BLUE RIDGE REGION OF VIRGINIA, by J. P. Nelson, Valuation Engineer, Chesapeake & Ohio Railway, Richmond, Va.

THE CONQUERORS, published by the Cleveland Engineering Society, Cleveland, O.

ADDITIONS TO MEMBERSHIP.

1397. Carson, C. E.,
Ia.

1939. Spencer, A. C.,
Supt. Const., Ferrocarriles Norte de Cuba, Moron, Camaguey, Cuba.

1942. Masters, F. H.,
Div. Eng., E. J. & E. Ry., Gary, Ind.

1945. Bailey, F. W.,
Supt. M. W., S. A. & A. P. Ry., Yoakum, Texas.

1948. Johnston, C. E.,
Gen. Man., K. C. S. Ry., Kansas City, Mo.

1949. Gillies, J. A.,
Eng. Sou. Dist., A. T. & S. F. Ry., Amarillo, Texas.

1950. Freygang, A. H.,
Asst. Engr., B. & O. R. R., Seymour, Ind.

1951. *Boucher, N. E.,
Sec'y, Northern White Cedar Assn., Minneapolis, Minn.

1952. Macpherson, A. W.,
Acting Ch. Eng., S. F. O. T. Rys., Oakland, Cal.

1954. Cate, C. E.,
Eng. M. W., S. P. Ry., Empalme, Sonora, Mexico.

1955. Fox, J. W.,
Val. Eng., Central of Georgia Ry., Savannah, Ga.

1956. Priest, R. N.,
Div. Eng., A. T. & S. F. Ry., Arkansas City, Kan.

1957. Sloan, E. B.,
Asst. Supt., S. P. R. R., Mazatlan, Sinaloa, Mexico.

1958. Davidson, A. M.,
Asst. Div. Eng., B. & O. R. R., Dayton, Ohio.

1959. Farlow, G. B.,
Asst. Eng., B. & O. R. R., Cincinnati, Ohio.

1960. Soete, F. X.,
Val. Eng., N. Y. O. & W. Ry., Middletown, N. Y.

1961. Flandreaux, C. S.,
Asst. Eng., N. Y. N. H. & H. R. R., Providence, R. I.

1962. Sears, T. H.,
Gen. Supt., A. T. & S. F. Ry., Amarillo, Texas.

1963. Gwyn, J. G.,
Ch. Eng., D. & R. G. R. R., Denver, Colo.

1964. Dansey, J. W.,
Asst. Eng., A. T. & S. F. Ry., Chicago, Ill.

1965. *Smith, H. J.,
Jr. Civil Eng., I. C. C., Washington, D. C.

1966. Carpenter, H. R.,
Asst. Ch. Eng., M. P. R. R., St. Louis, Mo.

1967. Swisher, H. H.,
Asst. Eng., C. & A. Ry., Chicago, Ill.

1968. Strong, C. C.,
Res. Eng., Rich. Term. Ry., Richmond, Va.

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*Associate.

1969. Olson, E. H.,
Office Eng., A. T. & S. F. Ry., Topeka, Kan.
1970. Crugar, E. L.,
Dist. Eng., I. C. R. R., New Orleans, La.
1971. *Ondarcho, S. C.,
Supt. Track, P. B. & N. E. R. R., Bethlehem, Pa.
1972. Blackie, G. F.,
Asst. Ch. Eng., N. C. & St. L. Ry., Nashville, Tenn.
1973. *Fordyce, J. R.,
Con. Eng., Little Rock, Ark.
1974. Ball, W. P.,
Dist. Br. Insp., B. & O. R. R., Cincinnati, Ohio.
1975. Gebert, S. C.,
Val. Dept., C. H. & D. Ry., Cincinnati, Ohio.
1976. McQuarrie, M. K.,
Eng., Dominion Atlantic Ry., Kentville, Nova Scotia.
1977. Nelson, J. P.,
Val. Eng., C. & O. Ry., Richmond, Va.
1978. Osgood, H. A.,
Asst. to V. P., Wabash Ry., St. Louis, Mo.
1979. Hulsizer, W. H.,
Asst. Eng. Val., U. P. R. R., Omaha, Neb.
1980. Ono, Rioye,
Civil Eng., Imperial Gov. Rys., Tokyo, Japan.
1981. Blum, Bernard,
Div. Eng., N. P. Ry., St. Paul, Minn.
1982. Niemeyer, C. H.,
Asst. Eng. M. W., Penna. R. R., Philadelphia, Pa.
1983. Doyle, T. L.,
Asst. Div. Eng., Penna. Lines, Logansport, Ind.

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*Associate.

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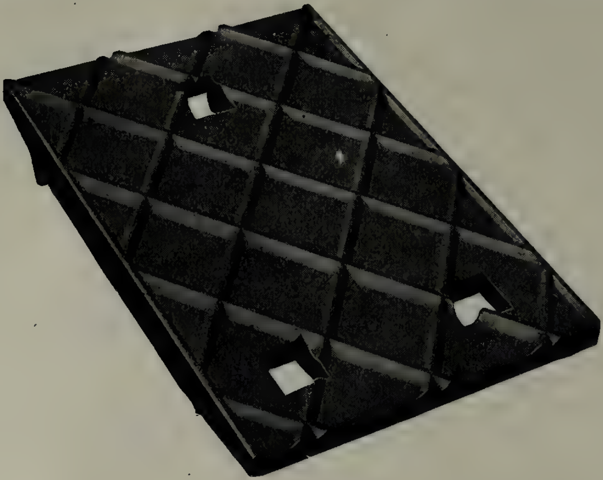

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RESIST CORROSION
ARE ROLLED END OVER END
AND DO NOT BREAK

Malleable Iron Tie Plates

Resist Corrosion
But Break

Steel Tie Plates

Do Not Resist Corrosion
Break unless Rolled End over End

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BULLETIN

OF THE

American Railway Engineering Association

Vol. 19, No. 197 . . . . JULY, 1917

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(Addenda to Edition of 1915)

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By W. H. Hoyt

Assistant Chief Engineer, Duluth, Missabe & Northern Railway

W. D. PENCE, *Editor,*
Chicago, Ill.

E. H. FRITCH, *Secretary,*
910 Michigan Avenue,
Chicago, Ill.

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American Railway Engineering Association

VOL. 19, No. 197 . . . . JULY, 1917

SUPPLEMENT TO MANUAL.

(ADDENDA TO EDITION OF 1915.)

FOREWORD.

In accordance with Rule 7 of the "General Rules for the Publication of the Manual," the Board of Direction of the American Railway Engineering Association has approved and authorized the publication of this "Supplement to Manual," Addenda to Edition of 1915, so as to be able to present promptly and concisely the amendments and addenda to the Manual, adopted after due consideration by the Association at the Annual Convention in March, 1917.

It has appeared best to the Board of Direction to issue at the present time these amendments and addenda, embodying the work of the 1917 Convention, in pamphlet form, supplementing the 1915 Edition of the Manual.

COMMITTEE I.

ROADWAY.

*MECHANICAL SHOVELS, LOCOMOTIVE CRANES AND DRAG-LINE EXCAVATORS; ALSO SHOVEL METHODS AND OPERATIONS, AND BLANK FORMS.

In the following matter, too detailed specifications are avoided, it being desired to direct attention to important features of good practice and point out proper methods of study and investigation, by which any competent Engineer may draw his own conclusion and secure the best possible results at the minimum cost.

The recommendations which are made are not in the nature of a specification, but are intended as a guide in the selection of this important equipment. Many manufacturers already embody the major part of these features in their standard design and many others can incorporate them without materially affecting the cost or standardization of their product. Certain features, however, are so important that radical changes in design, to those here recommended, would be a vast improvement in some cases. While it is recommended to buy standard equipment, care should be taken to select that of the best-known and most reliable makers and secure machines embodying as many of the features recommended here as possible. It is also advantageous for the maker to control the manufacture in every detail of all parts going into his finished product. The purchaser should have access to all parts of the manufacturers' plants at all times for purposes of inspection, etc.

Three cardinal points should be given careful attention in selecting machinery for roadway construction. These are in their order:

(1) Care in the selection, inspection and acceptance of all material that enters into every part of the machine.
(2) Design for strength and durability.
(3) Design for production.

The prompt delivery of repair parts and the accurate fit of these parts when received, is of utmost importance. This may be best judged by the general reputation of the different makes upon the market, and the supply of repair parts stocked at the nearest depot of supplies.

The machine should be so designed, in proportioning the strength of all parts, that breakage will be avoided. This is especially so with an over-powered engine, as a careless operator may easily wreck his machine.

The engines and other machinery should not be crowded, or unhandy to get at in case of repairs. The open-frame type of engines are the

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*Adopted, Vol. 18, 1917, pp. 626, 1510.

most desirable. All parts, as far as possible, should be free and not interfere with others so as to cause delay either in case of repairs or when moving.

The boilers should have ample capacity to operate continuously under full load, but the pressure regulation should be such as to eliminate danger of overtaxing the engines or other parts of the machine. Where lugs or braces are riveted to the boiler, or where pipe connections are made, the plates should be reinforced.

All parts should be interchangeable as far as possible, and bronze bushings are recommended for bearings in place of babbitt, split bushings being preferred where possible.

STEAM SHOVELS.

The general requirements for steam shovels are either so standard as to require no particular explanation or so very special as to make generalities impossible. A standard size and type of shovel manufactured by a well-known and reliable maker in a general way carries in itself ample guarantee, both in regard to its proper design and in respect to the quality of materials and workmanship entering into its construction. Certain special features, however, are noted that should be carefully borne in mind when purchasing this equipment.

Size.

The size of shovel used for any work must be decided by the character and quantity of excavation and the local conditions. In general, the commonest sizes are 60- to 80-ton shovels for the usual railway work. The following gradient of sizes may, however, be of service: For light grading, up to 25,000 c. y. per mile, where a shovel can be used economically, a light revolving shovel is to be desired. For 25,000 to 40,000 c. y. per mile, a shovel of 50 tons is a good size. For 40,000 to 60,000 c. y. per mile, a shovel of 60 to 80 is well suited. For anything over 60,000 c. y. per mile, the shovel may run up to well over 100 tons economically if its transportation is not too expensive, and if the ground is fit to carry the weight on sub-grade during excavation.

Special Specification.

Although it is usually unwise to depart materially from the standard design of a manufacturer in purchasing a steam shovel, mainly on account of the increase in cost resulting from such changes, and the liability of delays and other troubles connected with repairs, yet there are certain special features that are very often worth especially specifying. Also, as these are of distinct general advantage, the universal adoption of such a demand by all members of the American Railway Engineering Association would very quickly make them a standard practice with all reputable manufacturers.

The following list covers the principal items:

(1) As far as practical, all parts now made of cast-iron should be made of commercial cast-steel, except those made of manganese steel or similar alloy.

(2) The following parts should be made of manganese steel or a similar alloy:
Shipper shaft pinions,
Rack on dipper stick,
"A" frame collar,
Dipper breast, lip, teeth bases, teeth, hinges and latch catch.
(3) "A" frame should have bronze bushing.
(4) Swinging circle should have bronze bushing.
(5) All bearings should have bronze bushings instead of babbitt, split bushings to be used where possible.
(6) All sheaves for either chain or cable to be of steel and interchangeable, with bronze or metalline bushings. Rope sheaves should have turned grooves.
(7) All gears, except the shipper shaft pinion, to be of steel with cut teeth.
(8) Shafts and bearings to be the same size as far as possible.
(9) Both air brakes and hand brakes to all wheels.
(10) Double-bolt yoke design instead of saddle-block "U" bolt.
(11) When "U" bolt is used, the cross-section area should be increased 50 per cent. and flattened to fit the saddle yoke.
(12) An oil pump with forced lubrication in engine room.
(13) Rocking grates in boilers.
(14) All gears and dangerous moving parts to be guarded.
(15) Standard M. C. B. automatic couplings and M. C. B. trucks.
(16) Standard steel grab-irons, foot-steps and ladders outside house, as in freight car.

There are several radical structural changes that might be suggested, but as structural changes reduce the efficiency of shovel runners who are used to standard equipment and very seriously complicate the matter of repairs, such suggestions are not considered desirable here.

Delays.

The greatest cause of delay in steam-shovel work is in the removal of the excavated material. Too great care and attention cannot be given to securing proper and ample equipment in the matter of cars and locomotives, and in the proper systematization of service, track, transportation and disposal. The economic success of a steam shovel depends, above everything else, on having an empty car always ready to replace a loaded one under the dipper. Too great stress cannot be laid on this point. Careful management, thorough organization and unceasing superintendence and foresight only, however, can accomplish satisfactory results even with a thoroughly-equipped plant.

As the plant charge against steam-shovel work is always an important item, especially where the haul is long, requiring a large equipment in cars and locomotives, continuous operation is desirable. For this reason, either three 8-hour shifts or two 10-hour shifts are recommended. Where the service is not too trying on the machinery, three 8-hour shifts are more economical, if they do not upset other parts of the organization. When, however, the work is severe, two 10-hour shifts are preferable, as this arrangement gives two hours between each shift for repairs and overhaul in the plant. For night work, where electricity is not available, a small turbo-generator set, similar to that used on a locomotive, can be set up on the shovel for lighting the immediate works.

An old locomotive tender is a very valuable adjunct to a steam shovel, especially where delays may be caused from irregularity in coal and water supply.

The greatest cause of stoppage in the shovel proper is due to carelessness or incompetence in the operator. He should see that his engine-room and all moving parts are kept thoroughly cleaned and accessible. He should train his pit gang to watch the under-gearing and track. He must see that his boiler is washed out as often as necessary, depending on the water used, and that his flues, heads and sheets are tight and in repair. He must continually inspect all parts liable to wear or extraordinary strain and make renewals *before* the accident occurs. He must have a light and accurate hand on the propelling lever and must judge his load on the hoisting chain or cable, especially in an over-powered shovel. Heavy breakage in hoisting chains in such a case is almost always due to an unskilled or careless operator. The mechanical delays on a good shovel operated by a good runner are almost negligible.

A good works' superintendent or master mechanic can develop good shovel runners if he has time and patience. This, of course, is often difficult on railway work, especially in the Maintenance of Way operations. With average runners, the commonest repairs are as follows:

Hoisting cables.
Hoisting chains.
Swinging cable.
Teeth and tooth bases.
Friction bands and blocks.
"U" bolts or double bolts and yoke.
Pinions (especially shipper shaft).
Dipper latch and hinges.
Dipper stick (in hard digging).
Sheaves and pins (especially at end of boom and padlock block).
Shipper shaft.
Crankshaft on boom engine.
Eccentric straps.
Bearings.
Arm jacks.
Rack bolts.
Clevis strap between dipper and bail.
Ordinary engine repairs.
Ordinary boiler repairs.
Ordinary pipe fittings.

In the above list of most common repairs much of the trouble is undoubtedly due to lack of proper inspection and judgment in removing worn parts before they actually break, also to careless handling of the shovel when unusual strains arise in heavy digging. Where a good runner is secured the repairs will be very small. Where the work is near a base of supplies, the stock parts carried may be very small. There are also many repairs that may be made by the job blacksmith without special stock.

Repair parts to be stocked for emergencies when shovel is built as recommended, are as follows:

6 cold shuts for hoisting chain.
3 cold shuts for propelling chain.
1 swinging cable.
1 cable sheave and pin.
1 chain sheave and pin.
1 set teeth.
1 tooth base.
1 clevis strap connecting bail and dipper.
2 bolts for yoke block, or 2 "U" bolts.
1 set friction blocks.
1 pair each size, bronze bushings.
babbitt, if used anywhere.
1 set piston rings.
6 water glasses.
Miscellaneous assortment of packing.
Miscellaneous assortment of bolts.
Miscellaneous assortment of pipe and fittings.

The following list of tools is generally recommended. The assortment is very complete and may be reduced at discretion, depending on the proximity of other ready means of supply and repairs:

100-lb. anvil.
1 Axe, chopping, 4½-in.
1 Bar, buggy, 3-foot.
1 Bar, claw.
6 Bars, lining.
1 Bar, slice, fire, 5-foot.
1 Set blacksmith tools.
2 Blocks, snatch, 6-inch.
Set of bolt taps and dies, with holders.
1 Brush, chain, long handle.
2 Buckets, G. I., 2-gallon.
1 Cable, ⅝-in., 60 feet long.
1 Can, oil supply, 1-gallon (kerosene).
3 Carriers, timber.
6 Chisels (two flat, two round, two cape).
2 Containers, oil, 5-gallon.
1 Cooler, water, 8-gallon.
2 Cups, drinking, enamel.
1 Cutter, pipe.
1 Cutter, gage glass.
Set of twist drills.
1 Flue cleaner.
Forge, blacksmith, portable (with coal).
1 Gage, track.
1 Pair frogs, rerailing.
Set of taps and dies, with holders.
1 Hacksaw, adjustable, 8-inch to 12-inch.
2 Hammers, B. P., 1½ and 2 lbs.
6 Hammers, sledge, double-face, 8-lb.
1 Hammer, sledge, double-face, 16-lb.
1 Hoe, fire, 5-foot.
50 Feet hose, canvas, 1¼-inch.
2 Jacks, ball-bearing (size dependent on shovel).

1 Lantern, hand.
2 Oilers, long spout.
3 Padlocks.
3 Picks, clay.
1 Pot, tallow.
1 Rake, fire, 5-foot.
1 Ratchet, drill.
1 Saw, crosscut (two-man), 5-foot.
1 Saw, hand, crosscut, 26-inch.
1 Screwdriver, 12-inch.
6 Shovels, round point, short handle, No. 2.
1 Shovel, scoop, No. 3.
1 Vise, combination, pipe and bench.
4 Wrenches, monkey, 6-inch, 8-inch, 12-inch and 18-inch.
4 Wrenches, Stillson, 6-inch, 18-inch, 24-inch and 36-inch.
1 Set wrenches, single-end, ½-inch to 2½-inch.

Air-Operated Shovels.

The use of compressed air on a steam shovel is very common on tunnel and subway work, and is sometimes found in mining. It is not generally economical on outside work on account of the excessive plant charges. Its main object is to eliminate smoke and gas in a confined space where ventilation is difficult and expensive.

The main difference between air and steam operation is that air operation is quicker, and until an operator becomes accustomed to it he is liable to damage his machine, especially in the case of an over-powered shovel. Where air is used the boiler is ordinarily used as a receiver. Where this has been done, great care must be exercised in cleaning the boiler out completely before steam is used. As the air exhaust is inclined to freeze, a reheater is sometimes necessary. The boiler is sometimes used for this purpose, but great care must be exercised and a separate heater is preferred. Coke is the common fuel. Reheating, while an economy, is not generally advisable, on account of the gases, unless absolutely necessary.

Electric Shovels.

Electricity is sometimes applied to shovels as an operating power, but this is not in common use and has not yet met with general approval. It may, however, be readily applied to almost any standard shovel. The action is apt to be very sudden and the control sometimes unreliable, or at least, difficult to an ordinary operator. The great irregular peaks in the power consumption is also a serious factor as regards cost and in its effect on lights and other machinery on the same circuit. If power is purchased, care should be taken as to how the contract is worded in this respect.

The commonest application is in the case of light revolving shovels, which use a single motor and friction drive. There are more of these shovels electrified than all the other types put together, and in this case seems to give good satisfaction. Of the heavier shovels, there are comparatively few cases of electrification. Where this occurs, however, the three- and four-motor drive is the most common practice.

On the whole, electric shovels are so little used and under such general discussion, even among the electrical manufacturers, that they may still be said to be in the experimental stage and not subject to definite recommendation. When, however, electric power is cheap, or other circumstances indicate the advantage of its adoption, a special study and investigation is advised.

Electro-Hydraulic Shovels.

Electricity may very logically be applied indirectly to shovel operation. This is especially possible by means of hydraulic pumps and rams. This has been successfully done and the most desirable results obtained. By this means, absolute control of the operation is obtained, with full power at all speeds, and the electric power curve will be gratifyingly uniform. No standard design has been devised for this type of shovel, however, so that its use will develop only gradually.

Gasoline Shovels.

Gasoline motors are sometimes used to drive shovels, especially in the light revolving types, such as ditchers. The general application, however, seems far from imminent, and, like electrification, should be considered specially when occasion arises. The most logical application would be in arid regions where water is scarce and of poor quality for boiler purposes.

Tunnel Mucker.

One type of mechanical shovel that deserves special mention is the mucking machine, adapated to small tunnels and headings. Here the head-room is very low, often less than six feet, and the lateral clearance is equally restricted. Often the heading progress is entirely dependent on the mucking, especially where free drilling rock is encountered. The best type of machine for this purpose seems to be an electrically-operated shovel that casts directly back onto a conveyor, which in turn elevates and conveys the muck to cars in the rear. It must be remembered that all machines of this sort are subjected to "congested design" and liable to break down and delay. This form of shovel, like the electric shovel, is still in a rather experimental stage and not subject to definite recommendation.

LOCOMOTIVE CRANES.

Industrial.

Stability.

One of the greatest difficulties encountered when purchasing Locomotive Cranes arises from the absence of any standard rating for size and stability. At present, the term "15-ton crane," for instance, means absolutely nothing. As a matter of fact, the 15-ton crane of one make often has greater stability under equal loads and radii than a 20-ton crane of another. It is, therefore, recommended that the Association establish a standard rating, so that when a purchasing agent buys a 15-ton crane, American Railway Engineering Association rating, he knows exactly what he is getting in regard to capacity and stability. With this in view, the following general specification is recommended:

"The rating of a locomotive crane shall be given as the net tons that it will lift, at a 12-ft. horizontal radius, with the crane turned in any direction, the center of gravity remaining not less than three inches inside of the gage line of the track, when the water tank and coal bunkers are empty and neither rail clamps nor outriggers in use. Furthermore, the center of gravity shall also remain at least three inches inside the gage line of the track, with the crane turned in any direction, when the boom is raised to its highest position, the load removed from the hook, the water tank and coal bunkers full, and neither rail clamps nor outriggers in use."

Thus: A 15-ton crane is one that will raise 30,000 lbs. under the conditions just described, and which will equally retain its stability without load, as described.

It is also very important that the center of gravity of a crane, under working conditions, be as low as possible, and that the load be as closely concentrated about the center of rotation as possible, i. e., the main counterbalance or ballast should be in the non-rotating lower frame and the overhang of the rotating part be as small as possible. This will require a much heavier crane for a given rating than is often now the case, but will reduce the probability of overturning, which is the source of the greatest damage in locomotive crane operations.

Special Features.

Besides the above matters of rating and stability, there are certain features that are very important in crane design and construction. The following should be borne in mind when selecting a crane for any service where heavy duties and absence of delays are important:

(1) On all, except most restricted yard and shop services, two 4-wheel M. C. B. trucks are most strongly recommended. The wheel base should be as long as possible, and the trucks of very heavy pattern, to withstand the concentrated load on side lifts. M. C. B. automatic couplers with spring-draft mechanism should also be furnished. Standard safety appliances as required by statutes must be provided. Air and steam brakes and hand brakes should also be supplied.

(2) The best propelling mechanism is so designed that all gears are in perfect mesh under all circumstances, i. e., on straight and curved track and under shock, except when purposely disconnected for train haul.

(3) The large rotating gear ring and pinion should be of the best quality steel with cut teeth; forged steel without welds is preferred. The slip-ring design is recommended. It must be remembered that the whole weight of crane rotator and load is carried on this ring and ample bearing should be provided, either in rollers or trunnions, especially under the boom end of the frame.

(4) All parts of the crane mechanism should be readily accessible. That is, the engines, drums, shafting, gearing, and especially the clutches, should be so placed that each may be individually repaired or replaced without other dismantling.

(5) All shafts should be of nickel steel, the same size, and with interchangeable bronze bushings, as far as possibble. Split bushings are preferred, where possible.

(6) Drums should be interchangeable, as far as possible.

(7) Drums and sheaves should be large. This greatly increases the life of the cables.

(8) All gears should be of steel, with cut teeth.

(9) All castings should be of steel, where practical. Where cast-iron frames and beds are used, these should be very massive and properly webbed and filleted. Where steel frames and beds are used, however, care must be taken that actual strength and rigidity are not sacrificed to economy in weight.

(10) All sheaves should be of steel, with turned grooves, interchangeable, and have bronze or metalline bushings.

(11) Bolts and rivets at the rotating center should be avoided.

(12) No clutches or friction should be exposed to the weather.

(13) The levers should be simply and conveniently arranged and so located that the operator has a good view of his work.

(14) When the crane operates on parallel tracks, where a side swipe is possible from a passing train, convex mirrors should be so fixed as to give the operator a view back of his crane.

(15) All gears and dangerous moving parts should have safety guards.

(16) Boiler tubes must be replaceable without removing the boiler.

(17) The boom should be built up with the flanges of angles, channels, etc., turned in so as to expose the solid corner to possible blows and abuse.

Special Application.

A very valuable application for a locomotive crane, in excavation, is in combination with a steam shovel in deep, narrow cuts, where the spoil may be dumped at the side. The steam shovel may, in such a case, work at a high face in the cut, loading into large buckets, which would be picked up and dumped by the cranes traveling on the side of the cut above. This eliminates all complications usually incident to transportation and disposal under such circumstances.

It should also be remembered that a drag bucket may be used on a locomotive crane. When this is done, an extra large boom is usually erected and the rail clasps and outriggers put into service. The heavier sizes of crane are best adapted for this service, but even then the smaller sizes of drag bucket are recommended, and great care must be exercised by the operator not to put undue strain upon the frame and machinery.

Operator.

As in a steam shovel, the operator is responsible for most accidents and breakdowns. If careless, reckless or incompetent, he may upset or wreck his crane, even under the best operating conditions. Absolute cleanliness, careful inspection and the prompt replacement of worn parts before breakage occurs, as well as good judgment in handling loads, are the fundamental requirements for a successful and economical crane operator.

DRAG-LINE EXCAVATORS.

The drag-line excavator is an attempt to create a locomotive crane that will equal a steam shovel in capacity and handle certain classes of excavation for which a steam shovel is not suited. In this it has been partially successful, although under ordinary conditions and in heavy digging, the steam shovel is by all means the most popular. Where, however, the digging is light and may be deposited directly into the spoil bank without transportation, or where there is very much water or unstable bottom to contend with in the cut, the drag line finds its most useful field. Probably the greatest value of a drag-line excavator is in canal work, or sometimes on side borrows in railway work, especially where the digging is not too heavy and water is encountered.

In purchasing such equipment, only the most reliable and experienced manufacturers should be dealt with, and, where possible, it is advised to correspond with or personally discuss the actual performance of their individual machines with the users.

Regarding the construction details, the recommendations for locomotive cranes generally apply to drag-line excavators except in clearly distinct features, which are self-evident. The rotating circle is much larger. The propelling and traveling mechanism is very varied and deserving of study and careful consideration. The types of bucket are varied and the success of their application depends largely on the nature of their use. In general, a large amount of manganese steel should go into these buckets, especially where rock and boulders are to be encountered.

It is probable that with time and experience, drag-line excavators will become more highly perfected, the cost of maintenance will be greatly reduced and their use will become more general in all classes of work. At present they are still in the early stage of their development, as compared, for instance, with the steam shovel. With this in view, definite recommendations are not now considered expedient.

METHODS OF HANDLING STEAM-SHOVEL WORK.

Locomotives.

The type and size of locomotives used on steam-shovel work must depend on the character of the work, weight of trains, the length of haul and the local conditions. On maintenance work, ordinary road engines are usually well suited, especially if an ample tail track is provided in the pit so that too much shunting is not required. On construction, where the track is apt to be bad and curves abrupt, the four- or six-wheeled saddle-tank type is preferable, at least near the shovel. If the haul is long and the track is fair, heavier locomotives should be used in transportation.

In general, on construction where the tracks are inclined to be rough and curves sharp, the shorter the wheel base on a locomotive the better, within limits. Where road engines, or even heavy switch engines, are used, there is always danger of derailments and frame breakage. Where "dinkeys" are used, it is well to pay special attention to springs, brakes and the location of the center of gravity with reference to the wheel base. Some makes are so balanced that under heavy loads and on steep grades, two wheels are sometimes lifted clear off the track, with the natural resulting delays, if not damage.

Track.

The shovel track should be made up of 6-ft. sections, with strap connections. Bridles of ½-inch by 2-inch iron should be used, with wedge grips. A notched tie should be used as a check, behind the front trucks, supported by steel saddle clamps attached to the rail with wedged grips. Similar clamps should be placed before the front wheel without tie check. Nothing less than 60-lb. rail should be used under a shovel, and heavier rail should be used under the larger models. No spikes are used.

On the muck track in tunnels standard-length rails are used, spiked to the ties. Where no tail track is possible and the excavation is at a breast, drive rails are very useful. These consist of half-length rails laid on their sides, with the ball of the rail against the inside of the web of the last rail spiked down. As the breast is cleared away, these short rails are driven ahead and the cars are run out on the balls of the capsized rails. When a half-length is thus driven out, it is turned right side up and spiked lightly in position and the other half-length driven out in a similar manner. When both half-lengths have thus been driven out, both are removed and a standard-length rail spiked down in their place.

All track should be standard gage for outside work.

Cars.

Two-way side-dump cars are the most useful in general excavation. The best sizes are 12 to 30 cubic yards. They should be equipped with standard M. C. B. double trucks and be provided with both hand and air brakes. When air dumps are not employed the cars should be self-dumping when loaded, self-righting when empty, and have strong and easily-operated hand brakes, with brake wheels instead of cranks. Where wooden bodies are used, these should be heavily reinforced around the upper rim with steel angles, and steel-plated floors are generally desirable, even in earth excavation. The angle of dump should be as steep as possible within reasonable limits of height and re-righting ability.

When cars of small capacity are used, such as 4 to 10 cubic yards, only four wheels are used, although all cars should be spring-borne. In the case of four-wheeled cars, the wheel base should be long and the trucks articulated, if possible, to avoid derailment. All cars should be very substantially built, steel cars usually being preferred.

In tunnel cars, the wheel base should be fairly long, with spring journals or drop axles, and where they are for heading use, the overall height should not exceed 4 ft. 6 in. They should be very massively built, with heavy axles, fairly large wheels, steel linings and close clearances. End-dump cars for use on automatic dumping cage or tipple are usually preferred. When such cars are altered for steam-shovel work, the box may be raised to increase the capacity without serious expense.

Convertible cars, which may be used for commercial purposes, are often very valuable, as they may be used both as dump cars and as gondola cars.

Flat cars connected with aprons may be used on steam-shovel work where dumpers are not available. When such is the case, steel aprons are used over the bumpers, and an unloading plow is generally used for the dump. The following points should be observed in the selection of flat cars for steam-shovel work:

(1) The car should be strong enough for the purpose.

(2) Brake-wheels should be in good condition, and in case material is to be plowed off, they should be placed at side of car.

(3) Stake pockets should be in good condition and not spaced too far apart. Four feet apart in the center of the car, and closer at the ends, is good practice.

(4) Stakes should be strong enough to prevent accident or the derailment of the plow.

(5) The floors of the cars should be kept in good repair.

PLOWS AND SPREADERS.

For handling unloading plows, a cable with an auxiliary engine and drum is recommended. The machine should be able to develop sixty (60) tons pull, steam cylinders, 12 inches by 12 inches; diameter of drum 4½ feet, permitting four wraps of 1½-inch cable to be made. Steam supplied by the locomotive. The winding machinery should be placed on a specially-built or adapted car and protected from the weather.

When raising track, the center plow is recommended when the raise is light; side plows are recommended for making heavy fills or widening the bank.

The plow should be strong and massive. If the mold-board is curved throughout its length so as to make the angle of the entering wedge sharper than that of the tail of the plow, there is less breakage of stakes. The vertical slope of the mold-board should be sufficient to preclude climbing, especially towards the rear, in a side-dump plow. The larger and heavier plows are recommended for general use. The longer the plow and flatter the angle of thrust, the better satisfaction will be gained. The height of the mold-board should not be less than 48 inches on a center plow, or 54 inches on a side plow, and higher plows are usually more desirable.

The size of spreader selected will sometimes depend on special conditions or use, but in general the large size is most useful. For this type of machine the following features are recommended:

Form of spreader, 2 arms.

Pneumatic control by one man.

Maximum spread at least 40 ft., with extensions.

Vertical range of wing operation should be about 2 ft. above and below top rail.

Minimum width 10 feet, wings closed.

Maximum height in train 15 feet, wings closed.

Air and hand brakes.

Front plow to flange 2 inches below top rail, with cast-steel cutting edge and manganese steel wearing plates over rail.

The front plow should have extensions so that all material on track and 3 ft. to one side may be passed across track to the wing on the other side.

The center of gravity of the car should be as low as possible.

The wings should be heavy, strongly hinged and braced low to avoid twist.

In operation, the trucks should be watched and wheel flanges kept in perfect repair.

The locomotive runner should not be allowed to "charge the pile."

Vertical Limits.

It is impossible to establish set rules regarding the point where lifting track should stop and trestling begin when making embankments with trains. The character of the material is of great importance in the matter of cost. Some engineers consider that it is practically always preferable to trestle or block up the tracks without regard to the depth of fill, while others say it is advisable to raise the track as the fill progresses, up to 25 feet or more. On the average, from 6 to 10 feet are the commonest limits. With, however, the great fluctuation in the costs of both labor and materials, it is recommended that each case be treated as an individual problem. The cost of raising should be carefully figured, including the delays and interference caused to and by traffic where such exists, and this set against the cost of trestling, including labor and materials. It should be remembered that in some cases a "run-around" can be formed very cheaply, while in other places this requires either an auxiliary fill or trestle.

In estimating trestle for fills over which regular traffic is not to pass, the length of haul is important. Where the haul is less than two miles, light side-dumping cars may be used, and a very light trestle is required.

Of course, the geographical location of such work also has an important influence on this question, as climate, character and availability of fill materials, labor, lumber and other supplies vary enormously with different sections of the country.

Each engineer, familiar with his own section and the local conditions surrounding the work, is the man to estimate the relative cost and decide where raising track should stop and trestling should commence, either on new location or under existing track and traffic.

BLANK FORMS.

Five blank forms are recommended for reporting steam-shovel operations, as described and illustrated further on.

No forms are recommended for reporting crane operations, as this is so various and heterogeneous that a standard form is impossible.

No forms are recommended for reporting drag-line excavators, as they are very uncommon on railway work, and when used may be reported on Steam Shovel forms, or a special form modeled on these and made to apply to the individual case.

Of the Shovel Forms recommended, the first two, S. S. 1 and S. S. 2, are the reports of the Shovel and Dump Foremen, if the work is done by the railroad forces, or the inspectors, if it is a contract job. They deal purely with field conditions and are to be made out on the work, mainly while it is in progress. The front of the form, besides certain information shown as required at the top, provides space for repair parts, materials and supplies wanted and received and remarks which should act in the nature of a diary. The back is devoted to a tabulation of data and information covering the most important features of operation. Everything on this report, as far as possible, should be checked against the records of the timekeepers, storekeepers, etc., in the job offices. The size of the form is designed, when bound in a book, to fit comfortably into a man's pocket. These forms should be printed on good quality blue and yellow paper, respectively, and bound in books with stiff board covers, opening endwise. The sheets should be perforated at the top so that the forms may be torn out readily when completed. These forms should go to the Job Superintendent, or whoever is in immediate charge of the piece of work, and should also be accessible to the Master Mechanic or person in charge of the job plant as well.

When Forms S. S. 1 and S. S. 2 have been received from the various units of the job, the distribution clerk compiles Form S. S. 3, based on the information they contain, and from the records of the timekeepers, storekeepers, etc. This is laid before the Job Superintendent, or similar official, to be approved, signed and forwarded to the Division Engineer, or whoever has charge of that division or district. These figures should include everything chargeable to the job, including labor, clerical and engineering staff, material, plant and overhead of the job proper.

At the end of each month, Form S. S. 5 should be made out and forwarded, as described in S. S. 3. This is merely a monthly summary of the S. S. 3 reports.

When the S. S. 3 forms have been received from all the different jobs of that division or district, the distribution clerk of that office compiles the report shown in Form S. S. 4. This summarizes the information contained in the S. S. 3 forms and is built up in combination with the previous S. S. 4 forms, so that each interlocks with the one preceding and that immediately following it. When Form S. S. 4 is completed, it is laid before the Division Engineer or other proper official for his approval and signature, after which it is forwarded to the Chief Engineer or Vice-President in charge of construction and maintenance. In making out their report in daily form, the word "month" should be everywhere crossed out.

At the end of each month a monthly report should be made on the same form, S. S. 4, crossing out the word "day" where month appears and takes its place. This form is made up from the S. S. 3, 4 and 5 reports just received and forwarded as described for the S. S. 4 forms.

In Forms S. S. 3 and S. S. 4 average yardage costs are given beside the daily or monthly yardage cost, so that the difference may be seen at a glance as to whether the cost is increasing or decreasing, and explanations be immediately in order. The partial individual summaries of work done also shows the proportion of work completed without the usual analysis and arithmetic.

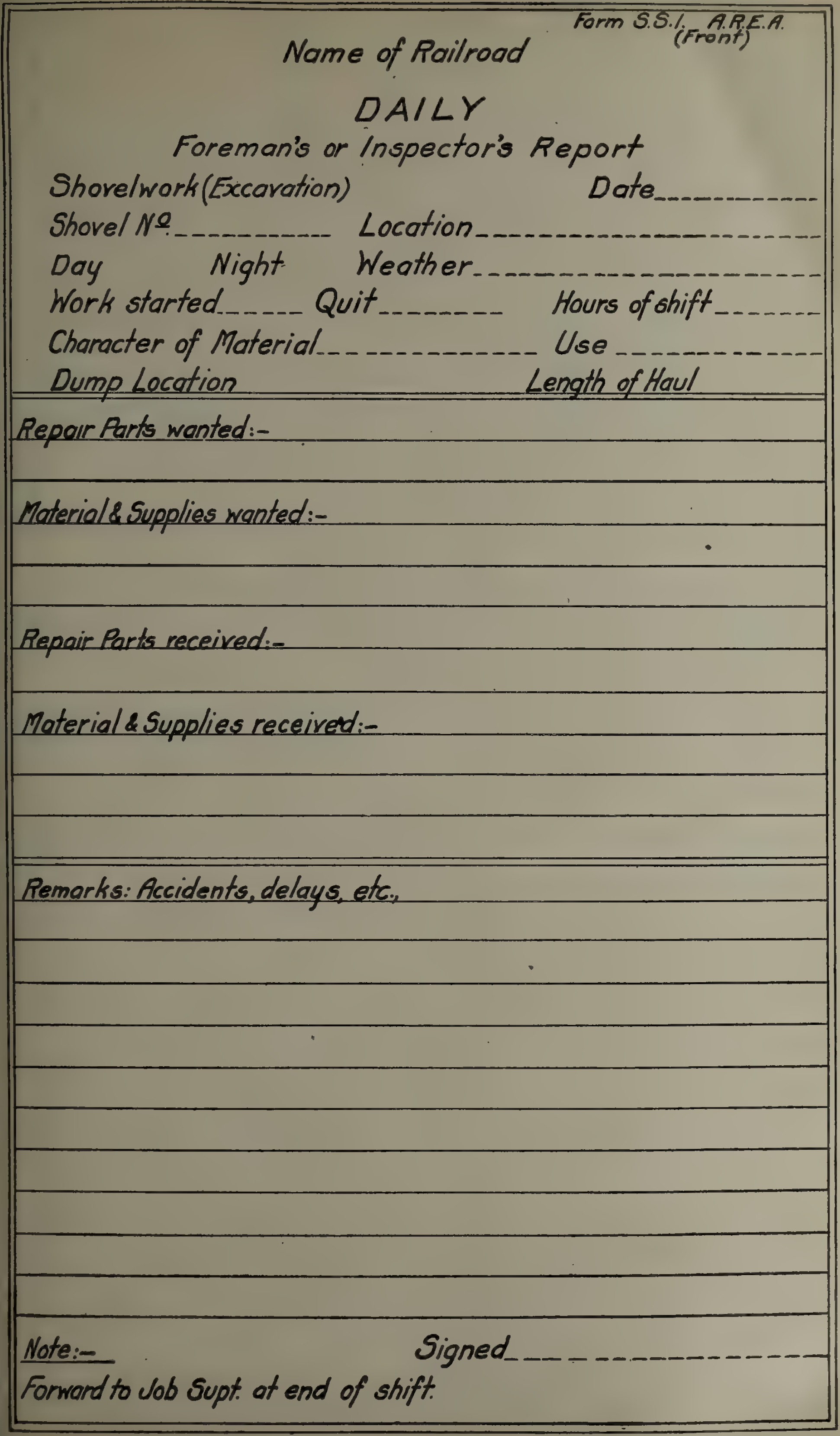
While these forms may appear superficially elaborate, they are in reality simple and very easily compiled, provided the work is properly systematized and kept up to date. The subjects treated in detail are those most vitally required for successful and economical job operation and supervision, and are designed to give the most valuable information to the parties best able to utilize it. In this connection, the number of carbon copies of Forms S. S. 3, 4 and 5 and their distribution to the various officials, other than those directly addressed, must be left to the local authority in that company.

These forms are designed for use on not over two-shift work. Where three eight-hour shifts are used, the forms may be readily altered to suit. No telegraphic report forms are recommended. If such are desired, they must necessarily be so brief and simple that their preparation from these here illustrated is so simple that special recommendation is not thought necessary.

If certain costs show increases that are not accounted for in the report, details may be secured from the distribution clerk, who should have all the individual items going to make up these costs posted and accessible in his distribution book. In the same way, details as to the cost of repairs to different pieces of equipment, the cost of individual supplies, etc., may be secured in the same manner. The distribution clerk should get his data daily from the timekeepers, storekeepers, etc., and should balance up with these separate departments every month. On contract work he should be given access to the above records of the contractor, if such reports are desired. If possible, the man selected for this work should be so constituted that he can maintain amicable relations with the contractor's men under trying circumstances.

SIZE OF FORMS.

The following sizes are recommended for the blank forms: Forms S. S. 1 and S. S. 2=5 in. by 8½ in.; Forms S. S. S. 3, S. S. 4 and S. S. S. 5=8½ in. by 14 in.



Form S.S.1. A.R.E.A.
(Front)

Name of Railroad

DAILY

Foreman's or Inspector's Report

Shovelwork (Excavation) Date__________

Shovel No.__________ Location______________________

Day Night Weather______________________

Work started_____ Quit_______ Hours of shift______

Character of Material_____________ Use____________

Dump Location Length of Haul

Repair Parts wanted:-

Material & Supplies wanted:-

Repair Parts received:-

Material & Supplies received:-

Remarks: Accidents, delays, etc.,

Note:- Signed_______________

Forward to Job Supt. at end of shift.

(A.R.E.A.) S.S.1. (back)

Engine Number	Trip No.	Time In.	Time Out.	Cars Loaded		Time Spent In									
						Loading Cars	Waiting Cars	Shifting Cars	Coal Water	Rep. Shovel	Rep. Track	Blast.	Other Delays		Total Lost.
													Kind	Time	
Totals															

Engine N$^{os.}$ at Shovel No. of Cars.

Other equipment on job.

Note:– Write in, kind and size of cars used, over columns of cars loaded.
L.D.=Large Dumpers; S.D.=Small Dumpers; F.C.=Flat Cars;
C.C.=Convertible (Center Dump); C.S.=Convertible (Side Dump)

Form S.3.2 A.R.E.A.
(Front)

Name of Railroad

DAILY
Foreman or Inspector's Report

Dump, Transportation, Spreading and Grading. Date __________

Serving Shovels № ______________________________

Character of Dump ______________ Location of Dump ______________

Day Night Weather ______________________

Work Started ________ Quit __________ Hours of Shift ________

Character of Material ____________________ Use __________________

Note- This report covers Transportation, Trackwork, Raising, Trestles, Unloading and Spreading

Repair Parts wanted:-

Material & Supplies wanted:-

Repair Parts received

Material & Supplies received:-

Remarks; Accidents, delays, etc.

Signed ____________________

Note-Forward to Job Supt. at end of Shift.

(A.R.E.A.) S.S.2
(back)

Note:- Write in, kind and size of cars used, over columns of cars unloaded
L.D.= Large Dumpers; S.D.= Small Dumpers; F.C.= Flat Cars; C.C.= Convertible (center dump)
C.S.= Convertible (side dump)

Engine Number	Time In.	Time Out.	Cars Unloaded		Time Spent In									
					Dumping	Spreading	Waiting for Cars	Shifting Cars	Shifting Track	Repairs		Other Delays		Total Lost
										To What	Time	Kind	Time	
Totals														

Road Engine Nos.________________________________

________________ Engine Nos. at Dump ________________

Other equipment on job________________________________

Note -
L.D. = Large Dumpers
S.D. = Small "
C.C. = Convertible center Dump
C.S. = " Side "
F.C. = Flat Cars

Form 5.5.3
A.R.E.A.

Name of Railroad

DAILY
SHOVEL JOB REPORT

To Division Engineer
From Job Superintendent

Weather ____________

Job Location

Character of Job

Force Acct. or Contract Nº

Shovel Nº											
Shovel Location											
Cut or Borrow											
Character of Material											
Use of Material Classification											
Point of Use											
Length of Haul											
Shift D. or N.											
Number of	Engines Working										
	F.C. "										
	L.D. "										
	S.D. "										
	C.C. "										
	C.S. "										
	"										
	Trains "										
	Plows "										
	Spreaders "										
Excavation	Total Cu. Yds. to Date										
	Total Cu. Yds. Today										
	Average Cu. Yds. per Day										
	Field Cost per C.Y. To Date										
	Field Cost per C.Y. Today										
Dump	Location										
	Character										
	Serving Shovels Nº										
	Total Cu. Yds. To Date										
	Total Cu. Yds. Today										
	Average Cu. Yds. per Day.										
	Field Cost per C.Y. Today										
	Average Field Cost for this Classification										

Total Field Cost of Job to Date

Total Field Cost of Job today

Note:-Cost of Dump includes Transportation, Dumping, Spreading, Trestles, etc.

Remarks (as to Delays, accidents, unusual costs, etc):-

Signed ______________________
Superintendent Job Nº _____

Date ____________

To Chief Engineer
From Division Engineer.

Name of Railroad.

Form S.9.4.
A.R.E.A.

DAILY MONTHLY

DIVISIONAL SHOVEL REPORT.

Job Number							
Force Acct: Cont: Nº							
Location							
Character of Work							
Total of Cu. Yds. in Job							
Total of Cu Yds Excavated to date							
Total Cu. Yds. Excavated To Day - This Month							
CUTS	Total Cu Yds on Job						
	Cu. Yds. Excavated To date						
	Average Cu. Yds Per day - Month						
	Cu Yds Excavated To day - This Month						
	Cost per Cu. Yd To day - This Month						
	Cost per Cu. Yd Average						
BORROW	Total Cu Yds on Job						
	Cu Yds Excavated to date						
	Average Cu. Yds. per day - Month						
	Cu. Yds Excavated Today - This Month						
	Cost per Cu Yds To day - This Month						
	Cost per Cu Yd Average						
FILL	Total Cu Yds on Job						
	Cu. Yds. Fill to date						
	Average Cu Yds Fill per day - Month						
	Cu Yds. Fill Today - This Month						
	Cost per Cu. Yd. Today - This Month						
	Cost per Cu. Yd Average						
SPOIL	Total Cu Yds on Job						
	Cu. Yds spoiled to date						
	Average Cu. Yds Spoiled per day - Month						
	Cu. Yds Spoiled To day - This Month						
	Cost per Cu. Yd Today - This Month						
	Cost per Cu. Yd Average						
BALLAST	Total Cu. Yds on Job						
	Cu. Yds placed to date						
	Average Cu. Yds placed per Day - Month						
	Cu. Yds Placed Today - This Month						
	Cost per Cu Yd Today - This Month						
	Cost per Cu. Yd Average						
Total Cost of Job Est:							
Total Cost of Job to date							
Percentage Completed.							

Remarks. (delays, accidents, unusual costs etc.):-

signed. ______________
Division Engineer.
Division ______
Date ________ 19__

Note -
L.D. = Large Dumpers
S.D. = Small "
C.C. = Convertible Center Dump
C.S. = " Side
F.C. = Flat Cars

Form 3.3.5
A.R.E.A.

Name of Railroad

MONTHLY
SHOVEL JOB REPORT

To Division Engineer
From Job Superintendent

Job Location

Character of Job

Force Acct. or Contract No

Shovel No											
Shovel Location											
Cut or Borrow											
Character of Material											
Use of Material											
Classification											
Point of Use											
Length of Haul											
Average No per Shift	Engines on Work										
	F.C. " "										
	L.D. " "										
	S.D. " "										
	C.C. " "										
	C.S. " "										
	Trains Working										
	Plows "										
	Spreaders "										
No of Days Worked											
Excavation	Total Cu. yds. To Date										
	Total Cu. yds. for Month										
	Average Cu. yds per Month										
	Average Cu. yds per day										
	Field Cost per C.Y. for Month										
	Average Field Cost per Cu. yd.										
Dump	Location										
	Character										
	Serving Shovels No										
	Total Cu. yds. To Date										
	Total Cu. yds. for Month										
	Average Cu. yds. per Month										
	Average Cu. yds. per day										
	Field Cost per C.Y. for Month										
	Average Field Cost for this classification										

Total Field Cost of Job to Date

Total Field Cost of Job for Month

Remarks :- (Delays, accidents, weather, Track repairs, supplies used, extra plant, unusual Costs etc.)

Signed ______________
Superintendent of Job No. _____

Date _______

*ALLOWANCE FOR SHRINKAGE.

(1) In determining the allowance for shrinkage to be made in a fill, it should be remembered primarily that it is easier to add to the height of a fill that settles than to lower the track if the settlement does not amount to as much as that anticipated in the original allowance. Therefore, unless the shrinkage of a material is well known in the conditions under which the fill is made, it is best to be well on the safe side; i. e., little or no allowance should be made in height; the extra material, when possible, being deposited where it will be conveniently available for raising the track, as required. The allowance in width should be from about 5 per cent. to 20 per cent. of the height of the fill, depending on the material and conditions.

(2) The material used for fill varies in shrinkage from sound, non-disintegrating rock, or gravel, which is least, to certain swelling clays, which give the greatest shrinkage both in compactibility and erosion at the slopes. While vegetable loam has a large percentage of actual shrinkage, it so quickly produces a protection cover of vegetation that the shrinkage due to erosion is usually small. Where frozen material must be used in making a fill, heavy settlement must be expected, and this is to be avoided where possible.

(3) The material and contour of the ground supporting the fill is also a matter of considerable importance. This is especially so where unstable material is encountered.

(4) The method of making the fill should also be carefully considered. When the tracks are being raised under traffic, the vertical shrinkage will be largely taken care of in the course of the work. When the fill is made by teams or such means as to reasonably tamp and compact the fill in thin layers as it is made, the same is true. Where, however, the fill is made by trestle and without puddling or other method of compacting, the settlement is apt to be considerable.

†GRADE SEPARATION.

(1) Whenever grade separation through densely built-up thoroughfares (short blocks, say, 12 to 15 crossings per mile), becomes imperative, elaborate studies of the kind and volume of traffic on each thoroughfare should be made and due record kept, with a view of eliminating or vacating certain of these crossings as wholly unjustifiable from a cost standpoint, and lateral streets at a less cost may be opened in their stead.

(2) If but a very few crossings are to be eliminated in an industrial district, with reasonable assurance that no others will be required, other things being equal, the method used should not disturb the tracks.

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*Adopted, Vol. 18, 1917, pp. 655, 1510.

†Adopted, Vol. 18, 1917, pp. 669, 1510.

(3) If several crossings are to be eliminated in an industrial district, other things being equal, the most efficient method is by track elevation.

(4) In a residential district, if grades and other conditions on the railway will permit, complete depression allowing the streets to remain at their original level, or nearly so, is the preferable method.

*SLOPES FOR HIGH ROCK CUTS OF FORTY FEET IN HEIGHT OR MORE.

(1) Where the depth of ballast on Class A track is greater than 12 inches under the tie the adopted standard berm shown on page 55 of the 1915 Manual should be added to each side of the standard ballast section adopted for the increased depth of ballast. If the sum obtained by the addition of the standard berm to the distance of the toe of the ballast slope from the center of the track ends in a fractional part of a foot, the sum is to be increased or decreased to the nearest whole number of feet.

(2) Rock cuts of forty (40) feet in height or more should be constructed at slopes of one-quarter to one.

(3) The advisable width for newly-constructed roadbed on high embankments of fifty (50) feet or more by dumping from the trestle should be as follows (no allowance to be made in height):

Anticipated shrinkage 7 per cent., add 10 per cent. of height to each shoulder.

Anticipated shrinkage 10 per cent., add 15 per cent. of height to each shoulder.

Anticipated shrinkage 15 per cent., add 22.5 per cent., of height to each shoulder.

---

*Adopted, Vol. 18, 1917, pp. 670, 1510.

COMMITTEE II.

BALLAST.

* DEFINITIONS.

Sub-Ballast.—Any material of a character superior to that in the adjacent cuts, which is spread on the finished sub-grade of the roadbed and below the top-ballast, to provide better drainage, prevent upheaval by frost and better distribute the load over the roadbed.

Top-Ballast.—Any material of a superior character spread over a sub-ballast to support the track structure, distribute the load to the sub-ballast and provide good initial drainage.

† EFFECTIVENESS OF BALLAST.

It is generally conceded that stone ballast is the most effective ballast, and experience has demonstrated that the best quality of each of the various kinds of ballast (using the definitions as found in the Manual) should fall about in the following order of effectiveness:

(1) Stone;
(2) Washed Gravel;
(3) Broken Slag (not granulated);
(4) Pit-Run Gravel;
(5) Chatts;
(6) Burnt Clay or Gumbo;
(7) Cinders.

‡ DEPTH OF BALLAST.

(1) The depth of ballast under the tie, on roadbed material, such as clay, loam, etc., subject to deformation by the application of live load, would seem to be not less than the spacing, center to center, of ties. On material which approximates the character of good sub-ballast (which will not be deformed by the application of live load), the minimum depth of ballast under bottom of tie should be 12 inches, to support the track structure; provide good initial drainage; provide against upheaval by frost action and serve as a cushion, and not for the purpose of uniformly distributing the load transmitted from the tie to the roadbed, which in such case would not be necessary.

(2) A sub-ballast blanket of cinders not less than 12 inches thick is effective in most cases in preventing mud and similar material working up into the top-ballast.

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*Adopted, Vol. 18, 1917, pp. 453, 1499.
†Adopted, Vol. 18, 1917, pp. 440, 1497.
‡Adopted, Vol. 18, 1917, pp. 455, 1502.

Proper drainage of the sub-grade is essential to success with any kind of ballast.

(3) Until sufficient tests are made under normal traffic conditions, the question of the proper depth of ballast must rest on opinion based on experience and evidence, such as the test of Director Schubert of the German Railways and the "Altoona Test."

COMMITTEE III.

TIES.

* SPECIFICATIONS FOR CROSS-TIES.

Add to Paragraph (2), "Woods to be Treated," the following:

Ties made from white oak, cypress and dense pine, showing a greater amount of sapwood than is permissible for ties to be used untreated, will be classed among the ties to be treated.

Add to Paragraph (3), "Material and Manufacture," the following:

† Ties of .... shall not have been cut or trees felled more than .... months at time of delivery.

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*Adopted, Vol. 18, 1917, pp. 493, 1507.

†To be inserted in localities where ties deteriorate very rapidly.

COMMITTEE V.

TRACK.

* MAINTENANCE OF SURFACE.

PROPER METHOD OF TAMPING.

Amend Paragraph (4), p. 160, 1915 Manual, to read:

Tools: Shovel, tamping pick, *tamping machine,* stone forks.

† SPECIFICATIONS FOR ORDINARY TRACK SPIKES.

Amend Paragraph (3), p. 128, 1915 Manual, to read:

The length under the head shall be not less, and not over one-quarter-inch more, than the dimensions shown.

‡DEFINITIONS.

Main Track.—The principal line or lines of a railway.

Branch Line.—The secondary line or lines of a railway.

Spur.—A line of railway diverging from a main or branch line, and over which no regular train service is maintained.

Main Track.—The running track of a railway whereon the movement of trains is controlled by timetable, train order or block signal.

For multiple main track generally the southerly or easterly main track shall be designated as the first main track and the adjacent one as the second main track, etc.

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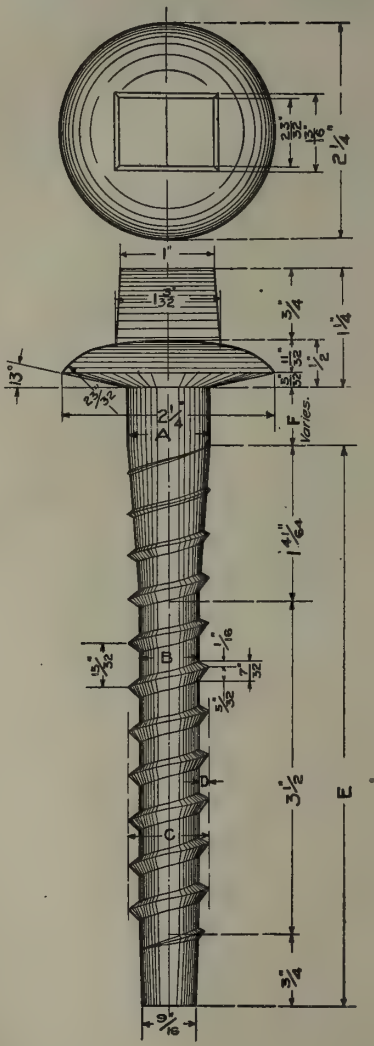
*Adopted, Vol. 18, 1917, pp. 401, 1481.
†Adopted, Vol. 18, 1917, pp. 404, 1487.
‡Adopted, Vol. 18, 1917, pp. 417, 1491.

*SCREW SPIKE.



	Letter	Max.	Stand.	Min.
Under Head	A	29/32	7/8	7/8
Root	B	21/32	5/8	5/8
Over Thread	C	29/32	7/8	7/8
Thread	D	9/64	1/8	1/8
Length	E	6 1/64	5 57/64	5 57/64
Length under Head	F	Varies according to thickness of Rail Base and Tie Plate		

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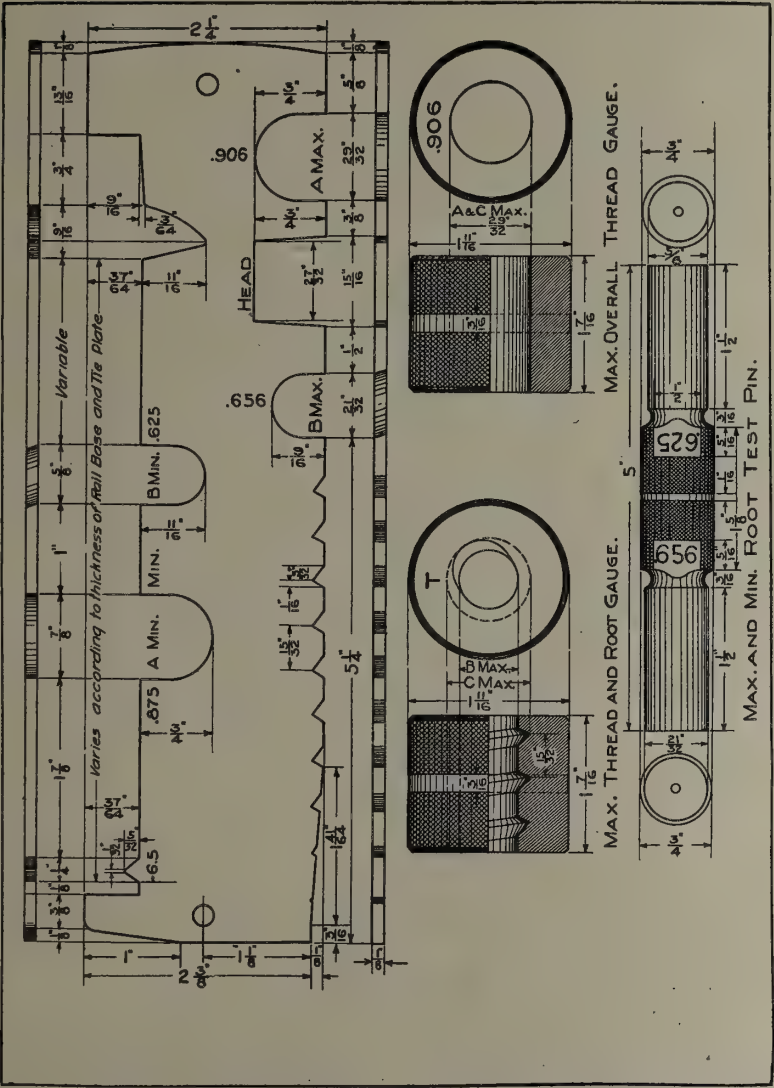
*Adopted, Vol. 18, 1917, pp. 428, 1488.

*TESTING GAGE FOR SCREW-SPIKE.


2 1/4"
.906
A MAX.
HEAD
.656
B MAX.
.625
B MIN.
MIN.
A MIN.
.875
6.5
Variable
Varies according to thickness of Rail Base and Tie Plate
5 1/4"
2 3/8"
.906
A&C MAX.
29/32"
1 11/16"
1 7/16"
MAX. OVERALL THREAD GAUGE.
T
B MAX.
C MAX.
MAX. THREAD AND ROOT GAUGE.
625
656
5"
MAX. AND MIN. ROOT TEST PIN.

---

*Adopted, Vol. 18, 1917, pp. 429, 1488.

COMMITTEE VI.

BUILDINGS.

*ENGINE HOUSES.

Add the following to page 191: "When there is an engine house without turntable and no 'Y' track or other means of turning provided, such engine house should preferably be equipped with smoke jacks at each end of each engine space."

†FREIGHT HOUSE SCALES.

The weighing of package freight at freight houses is very important from a revenue standpoint, and the railroads are installing a greater number of scales, and giving serious consideration to the weighing of all package freight, except possibly standard packages of known weight. There are some points where practically all the freight handled is of standard package freight, and at such houses very few scales are needed.

There are three classes of freight terminals, the largest being where both inbound and outbound houses are arranged in the same layout. At such points the following arrangement of scales is recommended:

Separate Outbound and Inbound Houses in Same Layout.

In outbound houses it is desirable to have a scale at every second door opening, or a maximum of 75-ft. centers. These to be located approximately 6 to 8 feet from the receiving side of the house.

In inbound houses it is desirable to have scales placed 100-ft. centers, as the maximum, and located on the receiving side.

Combination Inbound and Outbound Houses.

In layouts where one house handles both inbound and outbound freight, and where the business is heavy and diversified, the scales should be located preferably at every third door opening, or a maximum of 75-ft. centers. Where this number of scales are used they should be ample to take care of outbound weighing. Scales should be located on the driveway side of the house.

Combination Freight and Baggage Rooms.

At small outlying stations, where there is a combination baggage and freight room, fixed scale with platform level with the freight room floor, located preferably at one side of the door nearest the driveway side, is recommended, as at this point it will be less liable to damage from trunks or large packages.

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*Adopted, Vol. 18, 1917, pp. 815, 1529.

†Adopted, Vol. 18, 1917, pp. 815, 1530.

Location.

The ideal location for scales is to so place them that freight can be weighed as received and trucked to cars without re-handling.

Platforms.

In large houses scale platforms should be as small as practicable to accommodate the trucks used, and usually not over 6 feet by 8 feet, except at certain localities, where one or two large scales are necessary to handle freight that is especially bulky.

Capacity.

Scales for houses handling freight only should have a minimum capacity of four (4) tons. Higher capacity scales cost very little more and are economical from an operating and maintenance standpoint, as they will stand up better under the abuse they are usually subjected to.

At combination freight and baggage rooms fixed scale level with the freight house floor, with a minimum capacity of two (2) tons is recommended.

Type of Scale.

Where large volume of freight is handled during short periods, dial attachments to scales are recommended, as the additional cost and maintenance is justified by the increased amount of freight that can be handled.

*ASHPITS.

The ashpit is one of the most expensive structures on a railroad from a maintenance standpoint. Therefore, a great deal of thought should be given to the design.

The usual procedure at an ashpit is to drop or wash the hot ashes into the pit, and this heats up the walls and other parts of the structure. Then cold water is thrown on the ashes to cool them. This rapid cooling causes contraction in the material of which the structure is built, and when repeated many times weakens and sometimes destroys the structure.

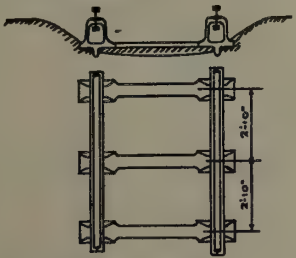

Fig. 1. Cast-Iron Tie Pit.

Another destructive element is the sulphuric acid produced by the water and sulphur in the ashes. This destroys the steel parts (coming in contact with it) at a rapid rate.

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*Adopted, Vol. 18, 1917, pp. 815, 1530.

Most ashpits are built of concrete, in which limestone is a principal ingredient. Hot ashes causes this limestone to swell and disintegrate, and in a short time the concrete will begin to spall off.

Vitrified brick facing has been used, but on account of the nature of the work and the tools used, experience shows that it is soon knocked off.

Slag and gravel concrete has been used in place of limestone concrete and makes a good substitute. If trap rock is available it makes a better concrete than either of the above materials.

Various Types of Pits.

(1) At outlying districts, where few engines are handled, cast-iron ties, approximately 12 inches high, are used to prevent burning wood ties. These should be located on spur tracks.

(2) Pit located between the track rails, of length to suit the business handled. The cinders are shoveled out on the track level and loaded by hand into cars or loaded into barrows and wasted at a convenient place.

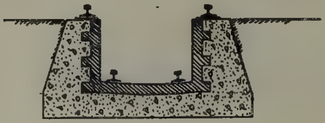

Fig. 2. Track Pit.

These pits are sometimes fitted with buckets which are handled by stationary, traveling or gantry cranes. Where stationary cranes are used, track is placed in the bottom of pit, buckets are equipped with trucks to permit of their being moved to the crane and loaded into cars.

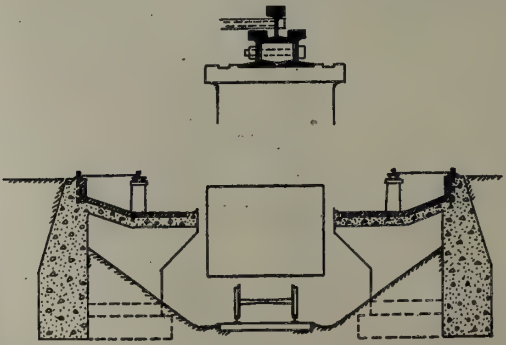

Fig. 3. Depressed Ash Car Track.

(3) Pit similar to Type No. 2, one side open, with depressed track alongside; the relative location of the top of the car with respect to the floor of the pit to be such as to give the easiest shoveling condition.

(4) Depressed pit filled with water, into which the cinders are dropped. One feature being to design the pit so that cinders will drop

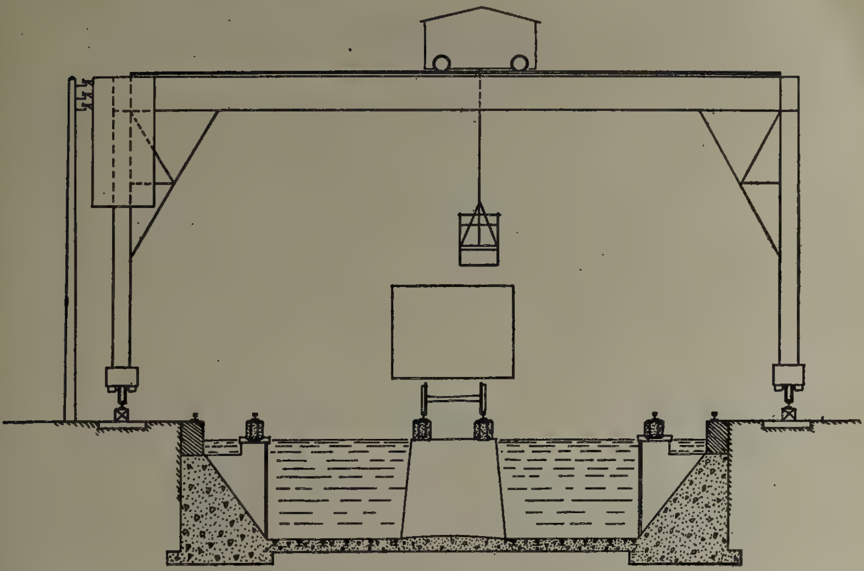

FIG. 4. WATER PIT WITH CRANE AND BUCKET.

directly into the water and reach the main body of the pit freely. Another feature being the easy removal of the cinders by grab bucket operated either by a gantry, traveling or locomotive crane.

Depth of water in pit should not be more than 5 feet below the drainage outlet.

Railing or iron posts with chains hooked between to be placed around pits, except across tracks where standard clearance diagram is to be followed.

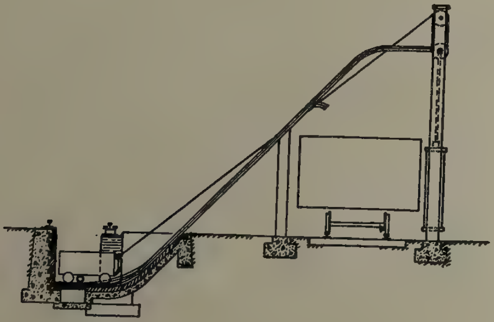

FIG. 5. TRACK PIT WITH BUCKET, POWER OPERATED.

(5) Pit equipped with bucket or car located under the track and hoisted by mechanical means, the cinder bucket or car running on rails

placed on an incline, car being run high enough to dump in a car located on a track parallel to and approximately 25-ft. centers from ash track.

General.

All types of pits should be equipped with water supply to wet down the hot cinders.

To warn and prevent persons from falling into the pit proper, an extension floor should be placed under track at both ends of all pits. This floor to be inclined on a 20 per cent. grade for a length of 15 feet.

Where twenty-five (25) or more engines are handled in twenty-four hours, the mechanical handling of cinders is recommended.

COMMITTEE VII.

WOODEN BRIDGES AND TRESTLES.

*COMPARATIVE MERITS OF BALLAST DECK AND REINFORCED CONCRETE TRESTLES.

(1) While in certain locations there is little probability of fire loss in creosoted ballast deck timber trestles, yet due to the very nature of the material used the reinforced concrete trestle has a decided advantage.

(2) The concrete structure is slightly superior to the timber structure for bridging waterways subject to flood currents, or wide fluctuations in elevation of water surface.

(3) Although the concrete trestle may possibly afford better service qualities than the wooden trestle, the matter is so intangible in character as to preclude a definite statement of relative merit.

(4) Where selection of type of trestle is optional and not influenced by other considerations, neither type of trestle has the advantage of the other in the matter of appearance.

(5) Notwithstanding the fact that the two materials are, with certain limitations, equally suitable for the construction of trestles, the use of concrete is more in accord with the theory of conservation of natural resources and industrial economy.

(6) Adoption of either type should be the result of carefully weighing, for each individual bridge, the greater economy of the timber trestle against the several advantages of the concrete not susceptible of mathematical demonstration.

†MERITS OF GALVANIZED IRON FASTENINGS FOR TIMBER TRESTLES AS COMPARED WITH PLAIN IRON AND STEEL FASTENINGS, ESPECIALLY IN RELATION TO THEIR USE ON CREOSOTED STRUCTURES.

(1) Creosoted timber has a tendency to protect from corrosion any plain iron or steel fastenings which are imbedded in the timber.

(2) The durability of such fastenings is at least equal to that of the creosoted timber used in trestles.

(3) In the use of timber treated with straight creosote, drift bolts or other fastenings being entirely covered by the timber, it is good practice to use plain iron or steel.

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*Adopted, Vol. 18, 1917, pp. 581, 1460.

†Adopted, Vol. 18, 1917, pp. 583, 1471.

(4) Such fastenings as are exposed to the action of brine drippings may be galvanized, but the information as to the increased life of fastenings so treated is not sufficient to state definitely that the expense of galvanizing is justified.

(5) It is not necessary to use galvanized fastenings in creosoted timber structures over salt water.

COMMITTEE VIII.

MASONRY.

*DEFINITIONS.

Pre-molded Concrete Piles.—Piles which are molded previous to driving.

Cast-in-place Piles.—Piles which are cast in holes in the ground.

†SPECIFICATIONS FOR CONSTRUCTING CONCRETE PILES.

The piles shall be made in accordance with the dimensions shown on the drawings.

The workmanship and materials shall be in accordance with the Specifications for Plain and Reinforced Concrete and Steel Reinforcement of the American Railway Engineering Association, with the following modifications:

The coarse aggregate shall consist of material such as crushed stone or gravel, varying in size from ¼-inch to ¾-inch. It shall be clean, hard, durable and free from all deleterious matter.

The proportions of the concrete shall be one part cement, two parts fine aggregate and four parts coarse aggregate.

The forms for concrete piles shall be made under the requirements for forms for concrete and reinforced concrete, as published in the Manual; they must be supported upon skids, spaced sufficiently close to prevent sagging of forms. The forms are generally collapsible, the bottom being left under the piles until they are sufficiently seasoned to permit turning upon the skids.

Concrete piles shall not be handled on the skids or moved to the site for driving, unless they have seasoned twenty-eight days. All concrete piles must be handled carefully, avoiding dropping or heavy jarring while in a horizontal or inclined position.

‡SPECIFICATIONS FOR DRIVING CONCRETE PILES.

Piles shall be protected while being driven with an approved cushion cap.

The driving or jetting of piles shall be governed by "Pile Driving—Principles of Practice," given in the Specifications for Workmanship for Pile and Frame Trestles in the Manual of the Association.

In driving, preference shall be given to a steam hammer. Where a drop-hammer is permitted, a heavy hammer with a short drop shall be used.

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*Adopted, Vol. 18, 1917, pp. 830, 1552.
†Adopted, Vol. 18, 1917, pp. 831, 1552.
‡Adopted, Vol. 18, 1917, pp. 832, 1557.

Any pile injured in driving or driven out of place shall be either replaced by a new pile, or pulled and redriven, as the case may require.

On sloping ground, and where necessary, a suitable hole shall be dug at the location of each pile to aid in holding it in proper position.

Before driving, the piles shall be carefully located and set to the line called for on the plan, and the pile driver leads held in proper position by means of guy lines. Unless otherwise called for on the plans, piles shall be driven as nearly as possible in a plumb position. Any pile out of plumb more than one-half inch per foot shall be pulled and redriven if so required by the engineer.

Reasonable efforts shall be made to drive the concrete piles to plan cut-off, the lengths of the piles having been determined by borings or test piles. Driving will be continued until this point is reached or until the following conditions are met: (Cases where driving is through soft soil to hard bottom or rock excepted.)

Piles which are to sustain a load of fifteen tons shall be driven to a point requiring not less than five blows to the last two inches of penetration, when driven with a No. 1 Vulcan Steam Hammer (weight of plunger 5,000 lbs., drop 36 inches) or other hammer of like mechanical effect.

Piles which are to sustain a load of twenty-five tons shall be driven to a point requiring not less than eight blows to the last two inches of penetration when driven with a No. 1 Vulcan Steam Hammer (weight of plunger 5,000 lbs., drop 36 inches) or other hammer of equivalent mechanical effect.

CUTTING OFF PILES.

Where it is not possible to drive concrete piles to plan cut-off, it will be necessary to remove a portion of the pile above this point, and, unless otherwise specified, a variation of four inches will be allowed above the plan cut-off for the inequalities of the tops of the piles. All loose parts of the head of cut-off piles shall be removed. Where reinforcement has to be cut off, it shall be done by a hack saw or oxy-acetylene torch.

*"CAST-IN-PLACE" PILES.

"Cast-in-place" piles may be divided into three general groups, according to their method of construction. The successive steps in each method are briefly enumerated below:

(a) A collapsible steel mandrel encased with a spirally reinforced sheet-steel casing is driven to the required penetration. The steel mandrel is then withdrawn and the steel casing, which is left in the ground as a form, is filled with concrete.

(b) A cylindrical casing with a core as a protecting and driving point is driven to the required penetration. The core is removed. A charge of concrete is placed and the core is used as a rammer to compress the surrounding soil at the base, thus forming an enlarged base to the pile. The casing, after being filled with wet concrete, is removed and the space left by the casing is allowed to fill with concrete, thus forming the pile.

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*Adopted, Vol. 18, 1917, pp. 833, 1561.

(c) Same as (b), except that the casing, which is driven with a protecting point, is left in the ground and the entire casing it filled with wet concrete. The casing is then removed as in (b).

Under conditions where "cast-in-place" piles may be used, the main advantages over the pre-molded piles are as follows:

(1) The length of the pile need not be definitely predetermined on account of being able to vary the lengths in driving as required.

(2) Saving in labor and material on account of each pile being made the required length before concrete is placed, thus saving cut-offs.

(3) The cost of handling materials is reduced.

(4) The delay resulting from allowing sufficient time for piles to season before they are handled is eliminated.

(5) The degree of penetration can be more accurately determined on account of the elastic cushion cap being unnecessary.

(6) Saving in reinforcement against handling, which in most cases is eliminated.

The nature of all the construction of a "cast-in-place" pile makes it essentially a foundation pile and it may not in all cases be a substitute for the original pre-cast pile. The expenses of moving and setting up the special equipment necessary for the various types makes them more economical on larger pieces of work than on those structures demanding a smaller number of piles.

In general, the various types of piling are either driven by companies owning or controlling the patented features or they are driven by contractors or others on a royalty basis. The diameter and shape of the piles vary with the type of pile used. Tapered round piles average an 8-inch tip and an 18-inch diameter at the top for a pile 23 ft. long. The straight piles are circular and have an average diameter of 17 inches.

The cost will vary from 85 cents to two dollars per linear foot with an average of perhaps one dollar, depending upon the number of piles driven and their lengths. Lengths are always measured from cut-off to tip of pile.

Loading of piles may be calculated from the same formula as that given for pre-cast piles, but as above stated, this can be more accurately determined in the "cast-in-place" piles.

*SURFACE FINISHES OF CONCRETE.

1. For all work not requiring decorative treatment, spaded finish is recommended as the most durable, the most readily applied and the most economical.
2. Coating with a wash of cement is not recommended.
3. Rubbing with carborundum bricks or wood floats is next to spading in ease of application and cost.
4. Tooling, alone or with rubbed margins and outlines, produces the most pleasing appearance, and where ornamentation is desired, these and the scrubbing methods are recommended.
5. Careful form work and continuous placing of the concrete are recommended as essential for all methods.

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*Adopted, Vol. 18, 1917, pp. 836, 1562.

SPECIFICATIONS.

(I) General.

1. The forms shall be made of lumber dressed to a uniform thickness and width, or dressed and matched to a uniform thickness and width, or lumber lined with metal, or metal, carefully built to exact dimensions and shape, with close level joints, smooth inside surfaces and sufficiently braced and tied together to be unyielding. The inside surfaces shall be washed just before the concrete is placed. Where the smoothest surface practicable with all wooden forms is desired, the inside surface shall be coated with light paraffin oil, boiled linseed oil or other approved material.

2. The whole extent of a surface to be finished shall be built in one continuous operation. The decorative treatment of the structure shall be such as to permit this. Where a continuous operation is not possible the seam or joint between the concrete placed first and that placed later shall be made water-tight with sheet lead or other metal imbedded equally in the two deposits of the concrete, or by some other approved method.

3. The same brand of cement shall be used throughout the whole of any surface or structure.

4. Where margins, patterns or different finish from the remainder of the surface are required, the forms shall be removed at the proper time to permit these to be laid off and finished in the best manner for the method specified.

5. All work shall be finished free from streaks, discolorations or other imperfections that impair the appearance or life of the finish.

(II) Spaded Finish.

1. The coarse aggregate shall be carefully worked back from the form into the mass of the concrete with spades, fine stone forks, bars or other suitable tools so as to bring a surface of mortar next the form. Care shall be taken to remove all air pockets and to prevent voids in the surface.

2. After the removal of the forms all voids in the surface shall be filled with a mortar made of the same proportions of cement and sand as those of the concrete and rubbed smooth and even with the surface with a wooden float. A trowel shall not be used for this purpose.

(III) Rubbed Finish—Carborundum or Cement Bricks.

1. The coarse aggregate shall be carefully worked back from the forms into the mass of the concrete with spades, fine stone forks or other suitable tools, so as to bring a surface of mortar against the form. Care shall be taken to remove air pockets and prevent voids in the surface.

2. The forms shall be carefully removed from the surface to be finished as early as practicable. All joint marks, projections and inequalities chipped off and all voids filled with a mortar made of the same proportions of cement and sand as those of the concrete. These surfaces shall then be thoroughly wet with water and while wet, rubbed to a smooth, uniform finish with a brick made of one part Portland cement and two parts or two and one-half parts sand; or with a No. 3 Carborun-

dum brick followed by a No. 30 or with a No. 24 Carborundum brick, as may be necessary to obtain the desired degree of smoothness.

3. No mortar or cement shall be applied except to fill distinct voids in the surface. Uneven places shall be smoothed by rubbing down and not by plastering. The surface shall be kept moist and protected from rapid drying for not less than three days.

(IV) Rubbed Finish—Wooden Floats.

1. The coarse aggregate shall be carefully worked back from the forms into the mass of the concrete with spades, fine stone forks or other suitable tools so as to bring a surface of mortar next the form. Especial care shall be taken to remove air pockets and to prevent voids in the surface.

2. The forms shall be carefully removed from the surfaces to be finished while the concrete is green. All joint marks, projections and inequalities chipped off and all voids filled with a mortar made of the same proportions of cement and sand as those of the concrete. The surfaces shall then be rubbed with soft wood floats and kept well flushed with water during the rubbing. When the desired finish is obtained the whole surface shall be thoroughly washed with water.

3. No mortar or cement shall be applied except to fill distinct holes or cavities. Uneven places shall be smoothed by rubbing down and not by plastering. The surface shall be kept moist and protected from rapid drying for not less than three days.

(V) Faced Surfaces.

1. The outside layer of the surface to be finished shall be composed of one (1) part cement and three (3) parts graded aggregate mixed to a stiff mortar. The aggregate shall be (description of aggregate) crushed to pass a sieve of three-eighths (⅜) inch mesh and be retained on a No. 100 sieve. The cement and the aggregate shall each be measured carefully and accurately for each batch and all batches shall be gaged with the same amount of water and carefully mixed in the same manner and for the same length of time, in order to obtain uniform surfaces.

2. For vertical surfaces the above surface mixture shall be placed against the forms by skilled workmen (using metal slip plates, where practicable) in a layer not less than one (1) inch thick, as the concrete is deposited in order that the surface mixture shall form a part of the mass of the concrete. Care shall be taken to remove air pockets and to prevent voids in the surface. For horizontal surfaces the surface mixture shall be placed as the concrete is deposited and before the concrete has set and where possible troweled or floated to an even surface.

(VI) Unfaced Surfaces.

1. The surface concrete shall be of the same mixture as specified for the body of the structure. The cement and the aggregate shall be measured carefully and accurately for each batch and all batches shall be gaged with the same amount of water and carefully mixed in the same manner and for the same length of time, in order to obtain uniform surfaces.

2. The concrete shall be spaded or worked against the form so as to make a surface of uniform density, free from air pockets and voids, with both coarse and fine aggregates exposed.

(2. The concrete shall be spaded vertically against the forms only as much as will remove air pockets and prevent voids, care being taken not to force the coarse aggregate away from the form.)

(VII) Washed or Scrubbed Finish.

1. As soon as the concrete has hardened sufficiently, but while it is still green, the forms shall be carefully removed from the surface to be finished and all voids filled with the surface mixture. The surface shall then be scrubbed with water and brushes of stiff fiber or of wire, until the aggregate is sufficiently exposed and projects slightly, but not enough to injure its adhesion to the mass. The whole surface shall then be washed with water until thoroughly clean. If necessary in order to remove the film of cement from the surface of the exposed aggregate or to better bring out the color, the surface shall be washed with a solution of one (1) part commercial hydrochloric acid and two and one-half (2½) parts water applied with brushes of stiff vegetable fiber. All traces of the acid shall be immediately and completely removed by washing with water. After the final washing the surface shall be kept moist and protected from rapid drying for not less than three (3) days.

(VIII) Acid Treated Finish.

1. After the forms are removed all voids shall be filled with the surface mixture. The surface to be finished shall then be washed with commercial hydrochloric or nitric acid diluted with water according to the age and hardness of the concrete. The strength of the solution shall be determined by trial on the work and shall only be such that the bond of the cement will be readily broken to the required depth. The solution shall be applied with stiff vegetable fiber brushes and the surface scrubbed until the aggregate is exposed to the desired amount.

2. As soon as the desired surface is obtained all traces of the acid shall be quickly and completely washed off with water to prevent its further action and the permanent discoloration of the surface.

NOTE.—For concrete that is but a few days old, a dilution of one part acid to six parts water may be sufficient. For concrete two weeks old a dilution of only two or three parts may be necessary.

(IX) Sand Blast Finish.

1. After the forms are removed all voids shall be filled with the surface mixture and left to harden as long as possible. All joint marks and projections shall be chipped off. The outside mortar shall then be cut away with a sandblast using a hard sand with angular grains. The nozzle shall not be larger than one-eighth (⅛) inch diameter and shall be held close to the surface. Care shall be taken to cut all the surface to a uniform depth. The work shall preferably be done between ten and fourteen days after the concrete is placed.

(X) Tooled Finish.

1. The proportions of cement and fine aggregate shall be such as to produce a mortar of a density or hardness as nearly equal to that of the coarse aggregate as possible.

2. After the forms are removed all voids shall be filled with the surface mixture and left to harden as long as possible. After the concrete has set and become hard, the surface to be finished shall be dressed (with a bush hammer of 3 to 6 cuts per inch, a crandall, a toothed pick, a pneumatic or an electric, or other desired tool) to a uniform depth and finish. Care shall be taken to make all margins and patterns straight and true.

*DESIGN OF RETAINING WALLS.

The following nomenclature is recommended:

Φ = the angle of repose of the filling.
Θ = the angle between the back of the wall and a horizontal line passing through the heel of the wall and extending from the back into the fill.
δ = angle of surcharge, which is the angle between a horizontal line and the surface of the filling. (It is recommended that values of $\delta = 0$ or $\delta = \Phi$ be used.)
λ = the angle between the resultant thrust P and a horizontal line.
h = vertical height of the wall in feet.
h^1 = height of surcharge in feet.
l = width of the base of the wall in feet.
e = distance from the center of the base to the intersection of the resultant thrust E and the base.
$a = \frac{l}{2} - e$ = distance from toe of wall to intersection of the resultant thrust E and the base.
P = the resultant earth pressure per foot of length of wall.
E = the resultant of the earth pressure and the weight of the wall.
F = vertical component of resultant E.
w = the weight of the filling per cubic foot.
w_1 = the weight of the masonry per cubic foot.
W = total weight of the wall per foot of length.
p_1 and p_2 = pressure per square foot on the foundation, due to F, at toe and heel, respectively.

FORMULAS.

The following formulas for vertical walls or for walls leaning away from the filling are based on Rankine's Theory, as given in Howe's "Retaining Walls," and in Ketchum's "Walls, Bins and Grain Elevators;" and the formulas for walls leaning toward the filling are based on a

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*Adopted, Vol. 18, 1917, pp. 875, 1564.

modification of Rankine's Theory, as given in Ketchum's "Walls, Bins and Grain Elevators."

For vertical walls with horizontal surcharge the pressure P is given by the formula

$$P=\frac{p_1}{2}wh^2\frac{p^2-\sin\phi}{1+\sin\phi}=\frac{1}{2}wh^2\tan^2\left(45^\circ-\frac{\phi}{2}\right)\ldots\ldots\ldots\ldots(1)$$

where P is parallel to the top surface, is normal to the wall, and is applied at one-third the height of the wall above the base.

For the vertical walls with a positive surcharge ϕ the pressure P is given by the formula,

$$P=\frac{1}{2}wh^2\cos\delta\frac{\cos\delta-\sqrt{\cos^2\delta-\cos^2\phi}}{\cos\delta+\sqrt{\cos^2\delta-\cos^2\phi}}\ldots\ldots\ldots\ldots(2)$$

where P is parallel to the top surface of the filling, makes an angle δ with a normal to the back of the wall, and is applied at one-third the height of the wall above the base. Where the surcharge δ is equal to the angle of repose Φ formula (2) becomes

$$P=\frac{1}{2}wh^2\cos\Phi\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

For a vertical wall with a loaded surcharge the resultant pressure on the back of the wall will be given by the formula

$$P=\frac{1}{2}wh\,(h+2h^1)\frac{1-\sin\phi}{1+\sin\phi}\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where h is the height of the wall and h^1 is the equivalent height of surcharge, which is equal to the surcharge per square foot divided by w, the weight per cubic foot of the filling.

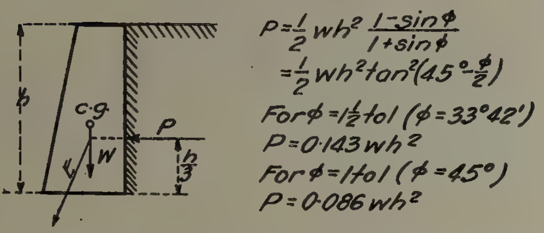
The resultant pressure is horizontal and is applied at a distance from the base of the wall equal to

$$y=\frac{h^2+3hh^1}{3\,(h+2h^1)}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

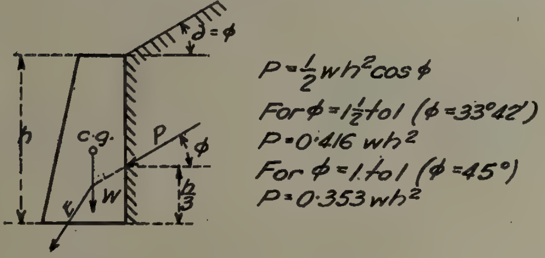
(a) In calculating the surcharge due to a track, the entire load shall be taken as distributed uniformly over a width of 14 feet for a single track or tracks spaced more than 14 feet centers, and the distance center to center of tracks where tracks are spaced less than 14 feet.

(b) In calculating the pressure on a retaining wall where the filling carries permanent tracks or structures, the full effect of the loaded surcharge shall be considered where the edge of the distributed load or the structure is vertically above the back edge of the heel of the wall. The effect of the loaded surcharge may be neglected where the edge of the distributed load or the structure is at a distance from the vertical line through the back edge of the heel of the wall equal to h, the height of the wall. For intermediate positions, the equivalent uniform surcharge load is to be taken as proportional. For example, for a track with the edge of the distributed load at a distance, $\frac{h}{2}$, from the vertical line through the back edge of the heel of the wall, the equivalent uniform surcharge load is one-half the normal distributed load distributed over the filling.

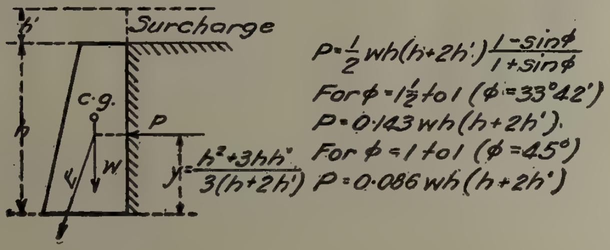
1 Vertical Wall, Horizontal Surcharge


h
c.g.
P
W
$\frac{h}{3}$
$P=\frac{1}{2}wh^2\frac{1-\sin\phi}{1+\sin\phi}$
$=\frac{1}{2}wh^2\tan^2(45°-\frac{\phi}{2})$
For $\phi=1\frac{1}{2}$ to 1 ($\phi=33°42'$)
$P=0{\cdot}143\,wh^2$
For $\phi=1$ to 1 ($\phi=45°$)
$P=0{\cdot}086\,wh^2$

2· Vertical Wall, Sloping Surcharge


$\delta=\phi$
h
c.g.
P
ϕ
W
$\frac{h}{3}$
$P=\frac{1}{2}wh^2\cos\phi$
For $\phi=1\frac{1}{2}$ to 1 ($\phi=33°42'$)
$P=0{\cdot}416\,wh^2$
For $\phi=1$ to 1 ($\phi=45°$)
$P=0{\cdot}353\,wh^2$

3· Vertical Wall, Loaded Surcharge

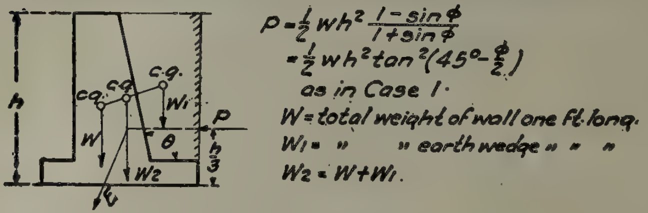

h'
Surcharge
h
c.g.
P
W
$y=\frac{h^2+3hh'}{3(h+2h')}$
$P=\frac{1}{2}wh(h+2h')\frac{1-\sin\phi}{1+\sin\phi}$
For $\phi=1\frac{1}{2}$ to 1 ($\phi=33°42'$)
$P=0{\cdot}143\,wh(h+2h')$
For $\phi=1$ to 1 ($\phi=45°$)
$P=0{\cdot}086\,wh(h+2h')$

Figs. 15 to 18 explain the distribution. The height of surcharge loading will be equal to the load per linear foot divided by b ($b=14$ feet for a single track railway). Where the edge of the distributed load cannot come nearer to the vertical line through the back of the heel of the wall than $h - x$, the equivalent uniformly distributed load in terms of height is

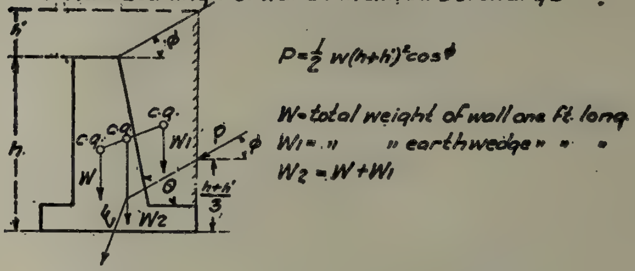
$$h_x' = h' \frac{x}{h}.$$

For walls leaning forward or walls with the base extending into the filling, the pressure of the filling on a vertical plane through back of the heel of the wall, as calculated above, is to be combined with the wedge of filling contained between this vertical plane and the back of the wall.

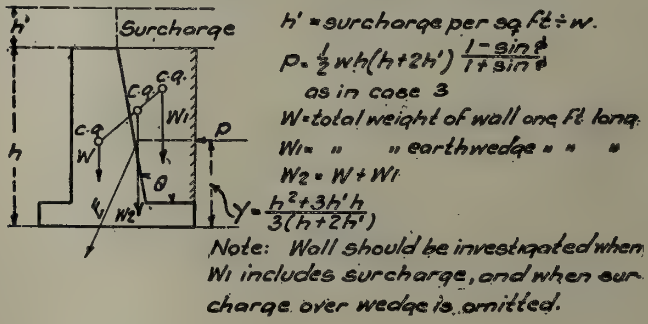
4. Wall Leaning Forward, Horizontal Surcharge


$P = \frac{1}{2} wh^2 \frac{1-\sin\phi}{1+\sin\phi}$
$= \frac{1}{2} wh^2 \tan^2(45° - \frac{\phi}{2})$
as in Case 1.
W = total weight of wall one ft. long.
W1 = " " earth wedge " " "
W2 = W + W1.
h
c.g.
c.g.
c.g.
W
W1
W2
θ
P
h/3

5. Wall Leaning Forward, Inclined Surcharge

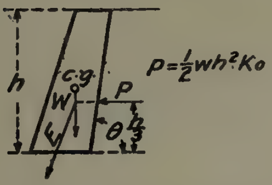

$P = \frac{1}{2} w(h+h')^2 \cos\phi$
W = total weight of wall one ft. long
W1 = " " earthwedge " " "
W2 = W + W1
h'
h
φ
c.g.
c.g.
c.g.
W
W1
W2
θ
P
φ
(h+h')/3

6. Wall Leaning Forward, Loaded Surcharge

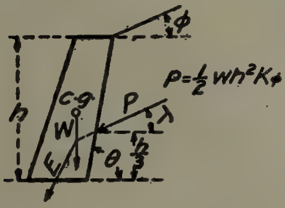

h' = surcharge per sq. ft. ÷ w.
$P = \frac{1}{2} wh(h+2h') \frac{1-\sin\phi}{1+\sin\phi}$
as in case 3
W = total weight of wall one ft. long.
W1 = " " earthwedge " " "
W2 = W + W1
$y = \frac{h^2+3h'h}{3(h+2h')}$
Note: Wall should be investigated when W1 includes surcharge, and when surcharge over wedge is omitted.
Surcharge
h'
h
c.g.
c.g.
c.g.
W
W1
W2
θ
P

For walls leaning toward the filling the resultant pressure P will be horizontal for a wall without surcharge or with a horizontal loaded surcharge, and will make an angle λ with the horizontal for a wall with a sloping surcharge. The values of λ will vary from δ, where the wall is vertical, to zero, where Rankine's Theory shows that the resultant pressure is horizontal. Values of λ are given in Figs. 10 and 11. Values K, where $P=\frac{1}{2}wh^2K$ are given in Figs. 10 and 11.

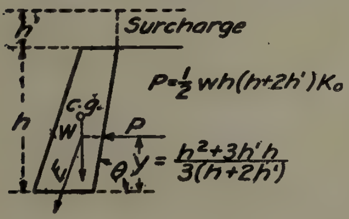
7·Wall Leaning Toward the Filling, Horizontal Surcharge

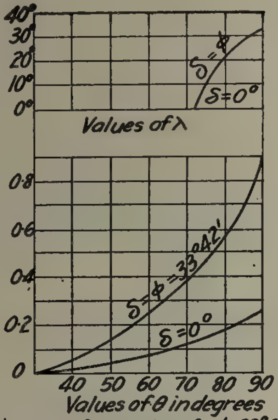


8·Wall Leaning Toward the Filling, Inclined Surcharge

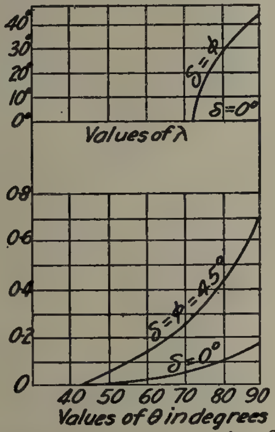


9·Wall Leaning Toward the Filling·Loaded Surcharge





10·Values of K_o and K_ϕ for $\phi=33°42'$



11·Values of K_o and K_ϕ for $\phi=45°\ 0'$

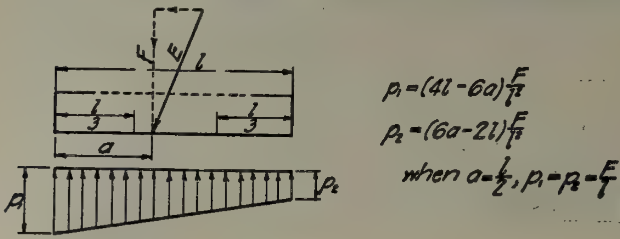
The formulas for the different cases above are given in Figs. 1 to 9.

DISCUSSION OF FORMULAS.

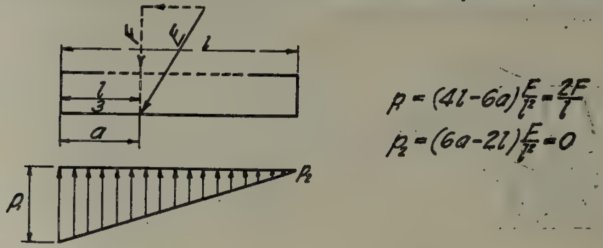
Cases 1 to 3 are for vertical walls without heels. The pressure P is the same as the pressure on a vertical plane in the filling. Vertical walls with heels come under cases 4 to 6.

Cases 4 to 6 are for walls with heels. The wall may be vertical or may lean forward, or may lean backward as long as the upper edge of the back of the wall is in front of the vertical plane through the edge of the heel.

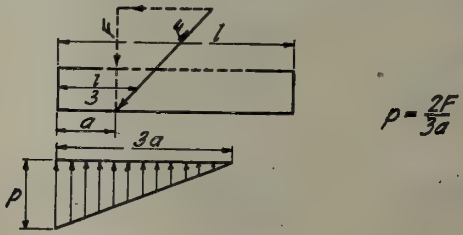
12 Pressures on Foundation, Resultant within Middle Third.


l
l/3
l/3
a
p_1
p_2
$p_1=(4l-6a)\frac{F}{l^2}$
$p_2=(6a-2l)\frac{F}{l^2}$
when $a=\frac{l}{2}$, $p_1=p_2=\frac{F}{l}$

13-Pressures on Foundation, Resultant at edge of Middle Third.


l
l/3
a
p_1
p_2
$p_1=(4l-6a)\frac{F}{l^2}=\frac{2F}{l}$
$p_2=(6a-2l)\frac{F}{l^2}=0$

14-Pressures on Foundation, Resultant outside Middle Third.



Cases 7 to 9 are for walls without heels. Walls with heels come under cases 4 to 6 as long as the upper edge of the back of the wall is in front of the vertical plane through the edge of the heel; if the upper edge of the back of the wall extends back of the vertical plane through the edge of the heel, the problem can be solved by combining the solutions of cases 4 to 6 and 7 to 9.

Fig #17

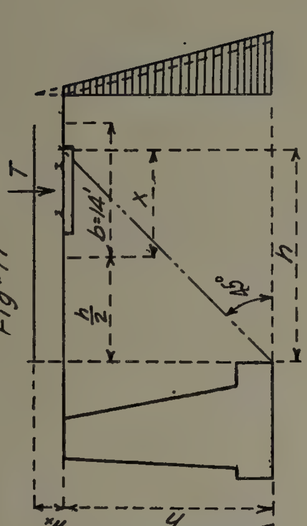


Fig #18

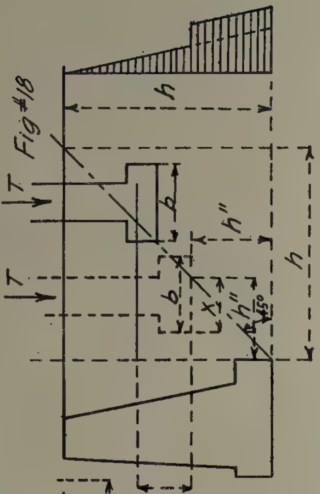


Fig #15

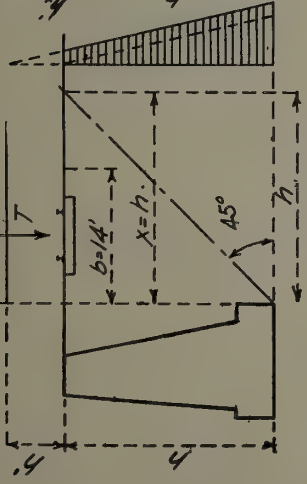
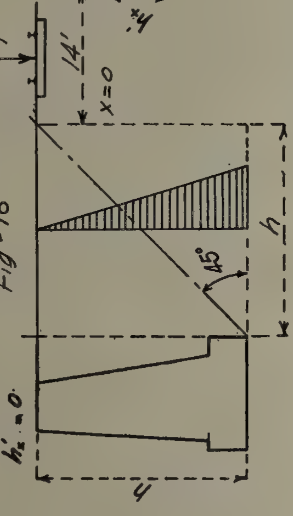


Fig #16



T= superimposed load per foot of wall b= width of distribution of T, in feet

$h' = T/BW$ $h'_x = h'\frac{x}{h}$ w= weight of backfilling per cu.ft.

PRESSURE ON FOUNDATIONS.

The pressures on foundations will be calculated by the following formulas:

Where a is equal to or greater than $\frac{l}{3}$.

Pressure at the toe

$$p_1 = (4l - 6a)\frac{F}{l^2} \qquad (6)$$

Pressure at the heel is

$$p_2 = (6a - 2l)\frac{F}{l^2} \qquad (7)$$

Where a is less than $\frac{l}{3}$, the pressure at the toe is

$$p_1 = \frac{2F}{3a} \qquad (8)$$

PRINCIPLES FOR DESIGN OF RETAINING WALLS.

The following principles should be observed in the design and construction of retaining walls:

(1) For usual conditions of the filling, use an angle of repose of 1½ to 1 ($\Phi = 33° \ 42'$). For dry sand or similar material, a slope of 1 to 1 ($\Phi = 45°$) may be used.

(2) The maximum pressure at the toe of the retaining wall should never exceed the safe bearing pressure on the material considered.

(3) When the retaining wall rests on a compressible material, where settlement may be expected, the resultant thrust E should strike at the middle or back of the middle of the base of the wall so that the wall will settle toward the filling ($a =$ or $> \frac{l}{2}$).

(4) When the retaining wall rests on a material where settlement may not be expected the resultant thrust E should not strike outside the middle third of the base ($a =$ or $> \frac{l}{3}$), except as noted in (5) below.

(5) Where the retaining wall rests on solid rock or is carried on piles the resultant thrust E may strike slightly outside the middle third, provided the wall is safe against overturning, and also provided the maximum allowable pressure is not exceeded.

(6) In order that the retaining wall may be safe against sliding, the frictional resistance of the base, combined with the abutting resistance of the earth in front of the wall, must be greater than the horizontal thrust on the back of the wall.

(7) The filling back of the wall should be carefully drained so that the wall may not be subjected to hydrostatic pressure.

(8) The foundation for a retaining wall should always be placed below frost line.

(9) A careful study should be made of the conditions in the design of each wall, and it should be remembered that no theoretical formulas can be more than an aid to the judgment of the experienced designer. The main value of theoretical formulas is in obtaining economical proportions, in obtaining a proper distribution of the stresses, and in making experience already gained more valuable.

*SPECIFICATIONS FOR PORTLAND CEMENT.

Definition.

1. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

(I) CHEMICAL PROPERTIES.

Chemical Limits.

2. The following limits shall not be exceeded:

Loss on ignition, per cent	4.00
Insoluble residue, per cent	0.85
Sulphuric anhydride (SO_2), per cent	2.00
Magnesia (MgO), per cent	5.00

(II) PHYSICAL PROPERTIES.

Specific Gravity.

3. The specific gravity of cement shall be not less than 3.10 (3.07 for white Portland cement). Should the test of cement as received fall below this requirement a second test may be made upon an ignited sample. The specific gravity test will not be made unless specifically ordered.

Fineness.

4. The residue on a standard No. 200 sieve shall not exceed 22 per cent. by weight.

Soundness.

5. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking or disintegration in the steam test for soundness.

Time of Setting.

6. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

Tensile Strength.

7. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes (see Section 51), composed of one

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*Adopted, Vol. 18, 1917, pp. 888, 1565.

part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at Test, days.	Storage of Briquettes.	Tensile Strength, lbs. per sq. in.
7	1 day in moist air, 6 days in water.......	200
28	1 day in moist air, 27 days in water.......	300

8. The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

(III) PACKAGES, MARKING AND STORAGE.

Packages and Marking.

9. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 lbs. net. A barrel shall contain 375 lbs. net.

Storage.

10. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

(IV) INSPECTION.

Inspection.

11. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test shall be omitted only when specifically ordered.

(V) REJECTION.

Rejection.

12. The cement may be rejected if it fails to meet any of the requirements of these specifications.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100 degrees Centigrade for one hour it meets this requirement.

14. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

15. Packages varying more than 5 per cent. from the specified weight may be rejected; and if the average weight of packages in any shipment,

as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

TESTS.

(VI) SAMPLING.

Number of Samples.

16. Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 8 lbs.

17. (*a*) *Individual Sample.*—If sampled in cars, one test sample shall be taken from each 50 barrels or fraction thereof. If sampled in bins, one sample shall be taken from each 100 barrels.

(*b*) *Composite Sample.*—If sampled in cars, one sample shall be taken from one sack in each 40 sacks (or 1 barrel in each 10 barrels) and combined to form one test sample. If sampled in bins or warehouses, one test sample shall represent not more than 200 barrels.

Method of Sampling.

18. Cement may be sampled at the mill by any of the following methods that may be practicable, as ordered:

(*a*) *From the Conveyor Delivering to the Bin.*—At least 8 lbs. of cement shall be taken from approximately each 100 barrels passing over the conveyor.

(*b*) *From Filled Bins by Means of Proper Sampling Tubes.*—Tubes inserted vertically may be used for sampling cement to a maximum depth of 10 ft. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(*c*) *From Filled Bins at Points of Discharge.*—Sufficient cement shall be drawn from the discharge openings to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

Treatment of Sample.

19. Samples preferably shall be shipped and stored in air-tight containers. Samples shall be passed through a sieve having 20 meshes per linear inch in order to thoroughly mix the sample, break up lumps and remove foreign materials.

(VII) CHEMICAL ANALYSIS.

LOSS ON IGNITION.

Method.

20. One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25 cc. capacity, as follows, using either method (*a*) or (*b*) as ordered:

(*a*) The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below, and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

(*b*) The crucible shall be placed in a muffle at any temperature between 900 and 1,000 degrees Centigrade for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

Permissible Variation.

21. A permissible variation of 0.25 will be allowed, and all results in excess of the specified limit, but within this permissible variation, shall be reported as 4 per cent.

INSOLUBLE RESIDUE.

Method.

22. To a 1-gr. sample of cement shall be added 10 cc. of water and 5cc. of concentrated hydrochloric acid; the liquid shall be warmed until effervescence ceases. The solution shall be diluted to 50 cc. and digested on a steam bath or hot plate until it is evident that decomposition of the cement is complete. The residue shall be filtered, washed with cold water, and the filter paper and contents digested in about 30 cc. of a 5-per-cent. solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with cold water, then with a few drops of hot hydrochloric acid, 1:9, and finally with hot water, and then ignited at a red heat and weighed as the insoluble residue.

Permissible Variation.

23. A permissible variation of 0.15 will be allowed, and all results in excess of the specified limit, but within this permissible variation, shall be reported as 0.85 per cent.

SULPHURIC ANHYDRIDE.

Method.

24. One gram of the cement shall be dissolved in 5 cc. of concentrated hydrochloric acid diluted with 5 cc. of water, with gentle warming; when solution is complete 40 cc. of water shall be added, the solution filtered, and the residue washed thoroughly with water. The solution shall be diluted to 250 cc. heated to boiling, and 10 cc. of a hot 10-per-cent. solution of barium chloride shall be added slowly, drop by drop, from a pipette and the boiling continued until the precipitate is well formed. The solution shall be digested on the steam bath until the precipitate has settled. The precipitate shall be filtered, washed, and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulphate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the per-

centage of sulphuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulphuric anhydride instead of using a separate sample.

Permissible Variation.

25. A permissible variation of 0.10 will be allowed, and all results in excess of the specified limit, but within this permissible variation, shall be reported as 2.00 per cent.

MAGNESIA.

Method.

26. To 0.5 gr. of the cement in an evaporating dish shall be added 10 cc. of water to prevent lumping, and then 10 cc. of concentrated hydrochloric acid. The liquid shall be gently heated and agitated until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration the residue may be heated to 150 or even 200 degrees Centigrade for one-half to one hour. The residue shall be treated with 10 cc. of concentrated hydrochloric acid diluted with an equal amount of water. The dish shall be covered and the solution digested for ten minutes on a steam bath or water bath. The diluted solution shall be filtered and the separated silica washed thoroughly with water.* Five cubic centimeters of concentrated hydrochloric acid and sufficient bromine water to precipitate any manganese which may be present shall be added to the filtrate (about 250 cc.). This shall be made alkaline with ammonium hydroxide, boiled until there is but a faint odor of ammonia, and the precipitated iron and aluminum hydroxides, after settling, shall be washed with hot water, once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitating vessel and dissolved in 10 cc. of hot hydrochloric acid. The paper shall be extracted with acid, the solution and washings being added to the main solution. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide and bromine water in a volume of about 100 cc., and the second precipitate shall be collected and washed on the filter used in the first instance if this is still intact. To the combined filtrates from the hydroxides of iron and aluminum, reduced in volume if need be, 1 cc. of ammonium hydroxide shall be added, the solution brought to boiling, 25 cc. of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well-defined granular form. The precipitate after one hour shall be filtered and washed, then with the filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner; after ignition, it shall be redissolved in hydrochloric acid and the solution diluted to 100 cc. Ammonia shall be added in slight excess and the liquid boiled. The lime shall then be reprecipitated by ammonium oxalate, allowed to stand until settled, filtered and washed. The combined

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*Since this procedure does not involve the determination of silica, a second evaporation is unnecessary.

filtrates from the calcium precipitates shall be acidified with hydrochloric acid, concentrated on the steam bath to about 150 cc., and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little aluminum and iron and perhaps calcium). When cool, 10 cc. of saturated solution of sodium-ammonium-hydrogen phosphate shall be added with constant stirring. When the crystallin ammonium-magnesium orthophosphate has formed, ammonia shall be added in moderate excess. The solution shall be set aside for several hours in a cool place, filtered and washed with water containing 2.5 per cent. of NH_3. The precipitate shall be dissolved in a small quantity of hot hydrochloric acid, the solution diluted to about 100 cc., 1 cc. of a saturated solution of sodium-ammonium-hydrogen phosphate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about two hours, filtered and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesia. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum and manganese as phosphates.

Permissible Variation.

27. A permissible variation of 0.4 will be allowed, and all results in excess of the specified limit, but within this permissible variation, shall be reported as 5.00 per cent.

(VIII) DETERMINATION OF SPECIFIC GRAVITY.

Apparatus.

28. The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in Fig. 1. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not lighter than 62 degrees Baumé, shall be used in making this determination.

Method.

29. The flask shall be filled with either of these liquids to a point on the stem between zero and one cubic centimeter, and 64 g. of cement, of the same temperature as the liquid, shall be slowly introduced, taking care that the cement does not adhere to the inside of the flask above the liquid and to free the cement from air by rolling the flask in an inclined position. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 g. of the cement.

The specific gravity shall then be obtained from the formula,

$$\text{Specific gravity} = \frac{\text{Weight of cement (g.)}}{\text{Displaced volume (cc.)}}$$

30. The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0.5 degrees Centigrade. The results of repeated tests should agree within 0.01.

31. The determination of specific gravity shall be made on the cement as received; if it falls below 3.10, a second determination shall be made after igniting the sample as described in Section 20.

(IX) DETERMINATION OF FINENESS.

Apparatus.

32. Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire, and mounted without distortion on frames not less than 1½ in. below the top of the frame. The sieve frames shall be circular, approximately 8 in. in diameter, and may be provided with a pan and cover.

33. A standard No. 200 sieve is one having nominally an 0.0029-in. opening and 200 wires per inch standardized by the U. S. Bureau of Standards, and conforming to the following requirements:

The No. 200 sieve should have 200 wires per inch, and the number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between adjacent parallel wires shall be more than 0.0050 inch in width. The diameter of the wire should be 0.0021 in. and the average diameter shall not be outside the limits 0.0019 to 0.0023 in. The value of the sieve as determined by sieving tests made in conformity with the standard specification for these tests on a standardized cement which gives a residue of 25 to 50 per cent. on the No. 200 sieve, or on other similarly graded material, shall not allow a variation of more than 1.5 per cent. above or below the standards maintained by the Bureau of Standards.

Method.

34. The test shall be made with 50 g. of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired, and shall be held in one hand in a slightly inclined position so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the up stroke. The sieve shall be turned every 20 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 g. passes through in one minute of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample.

35. Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in Section 34.

Permissible Variation.

36. A permissible variation of 1 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 22 per cent.

(x) MIXING CEMENT PASTES AND MORTARS.

Method.

37. The quantity of dry material to be mixed at one time shall not exceed 1,000 g. nor be of less than 500 g. The proportions of cement or cement and sand shall be stated by weight in grams of the dry materials; the quantity of water shall be expressed in cubic centimeters (1 cc. of water = 1 g.). The dry materials shall be weighed, placed upon a non-absorbent surface, thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of ½ minute for the

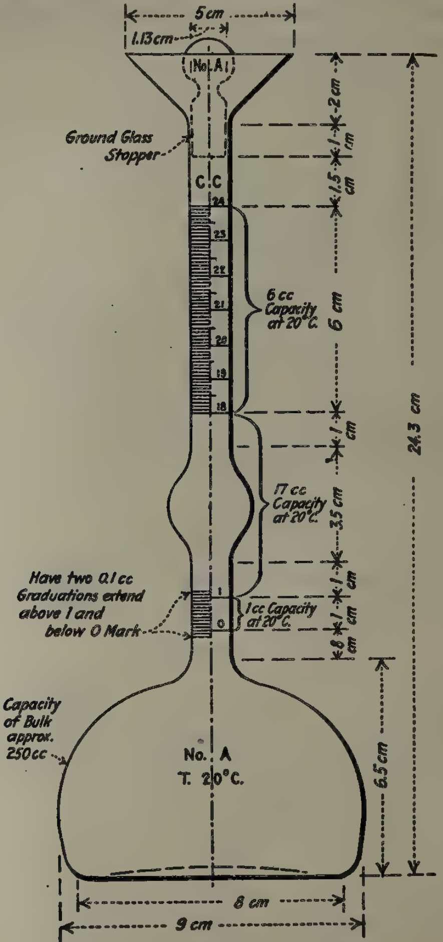

Fig. 1.—Le Chatelier Apparatus.

absorption of the water the operation shall be completed by continuous, vigorous mixing, squeezing and kneading with the hands for at least one minute.* During the operation of mixing, the hands should be protected by rubber gloves.

38. The temperature of the room and the mixing water shall be maintained as nearly as practicable at 21 degrees Centigrade (70 degrees Fahrenheit).

(XI) NORMAL CONSISTENCY.

Apparatus.

39. The Vicat apparatus consists of a frame *A* (Fig. 2) bearing a movable rod *B*, weighing 300 g., one end *C* being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle *D*, 1mm. in diameter, 6 cm. long. The rod is reversible, and can be held in any desired position by a screw *E*, and has midway between the ends a mark *F*, which moves under a scale (graduated to millimeters) attached to the

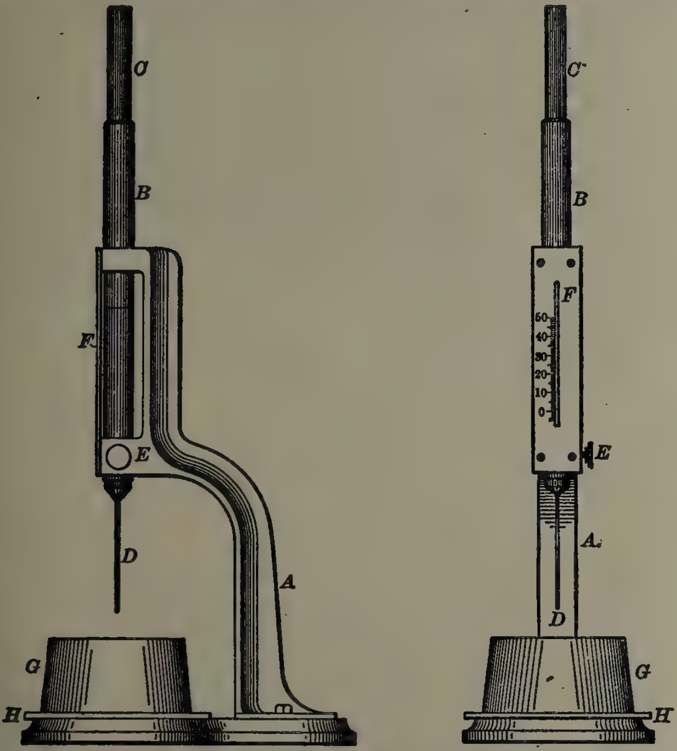

FIG. 2.—VICAT APPARATUS.

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*In order to secure uniformity in the results of tests for the time of setting and tensile strength the manner of mixing above described should be carefully followed. At least one minute is necessary to obtain the desired plasticity which is not appreciably affected by continuing the mixing for several minutes. The exact time necessary is dependent upon the personal equation of the operator. The error in mixing should be on the side of overmixing.

frame *A*. The paste is held in a conical, hard-rubber ring, *G*, 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate *H* about 10 cm. square.

Method.

40. In making the determination, 500 g. of cement, with a measured quantity of water, shall be kneaded into a paste, as described in Section 37, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 in. apart; the ball resting in the palm of one hand shall be pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed on its larger end on a glass plate and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall be then read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm. below the original surface in ½ minute after being released. The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the normal consistency is obtained. The amount of water required shall be expressed in percentage by weight of the dry cement.

TABLE 1.—PERCENTAGE OF WATER FOR STANDARD MORTARS.

Percentage of Water for Neat Cement Paste of Normal Consistency.	Percentage of Water for One Cement Three Standard Ottawa Sand.	Percentage of Water for Neat Cement Paste of Normal Consistency.	Percentage of Water for One Cement Three Standard Ottawa Sand.
15	9.0	23	10.3
16	9.2	24	10.5
17	9.3	25	10.7
18	9.5	26	10.8
19	9.7	27	11.0
20	9.8	28	11.2
21	10.0	29	11.3
22	10.2	30	11.5

41. The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal consistency from the same sample of cement. Having determined the normal consistency of the sam-

ple, the consistency of standard mortar made from the same sample shall be as indicated in Table 1, the values being in percentage of the combined dry weights of the cement and standard sand.

(XII) *DETERMINATION OF SOUNDNESS.

Apparatus.

42. A steam apparatus, which can be maintained at a temperature between 98 and 100 degrees Centigrade, or one similar to that shown in Fig. 3, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position.

Method.

43. A pat from cement paste of normal consistency about 3 inches in diameter, ½-in. thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 in. square, and stored in moist air for 24 hours. In molding the pat, the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the center.

44. The pat shall then be placed in an atmosphere of steam at a temperature between 98 and 100 degrees Centigrade upon a suitable support 1 in. above boiling water for 5 hours.

45. Should the pat leave the plate, distortion may be detected best with a straight edge applied to the surface which was in contact with the plate.

(XIII) DETERMINATION OF TIME OF SETTING.

46. The following are alternate methods, either of which may be used as ordered:

Vicat Apparatus.

47. The time of setting shall be determined with the Vicat apparatus described in Section 39. (See Fig. 2.)

Vicat Method.

48. A paste of normal consistency shall be molded in the hard-rubber ring *G* as described in Section 40, and placed under the rod *B*, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in ½ minute after being released; and the final set, when the needle does not sink visibly into the paste. The test pieces shall be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be

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*Unsoundness is usually manifested by change in volume which causes distortion, cracking, checking or disintegration.

Pats improperly made or exposed to drying may develop what are known as shrinkage cracks within the first 24 hours and are not an indication of unsoundness. These conditions are illustrated in Fig. 4.

The failure of the pats to remain on the glass or the cracking of the glass to which the pats are attached does not necessarily indicate unsoundness.

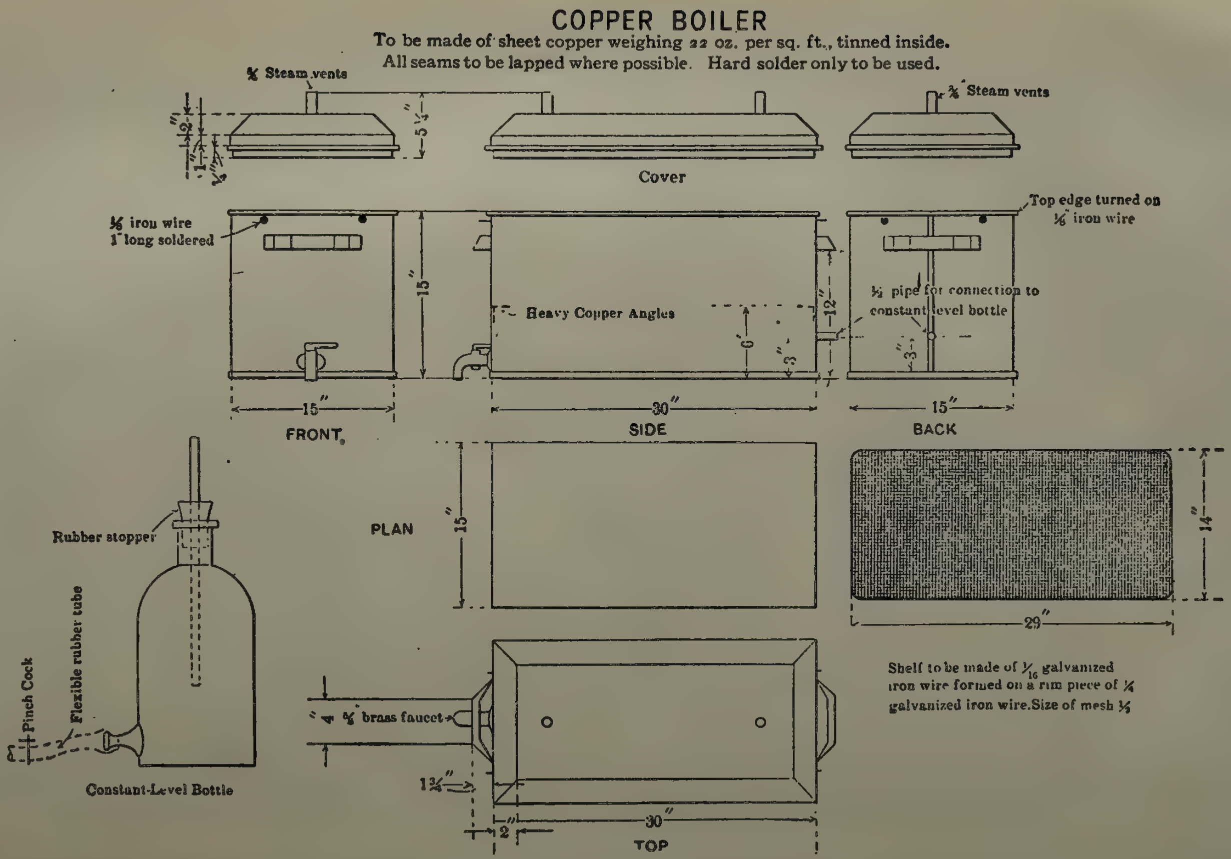

COPPER BOILER
To be made of sheet copper weighing 22 oz. per sq. ft., tinned inside.
All seams to be lapped where possible. Hard solder only to be used.
⅜ Steam vents
⅜" Steam vents
5½"
½"
1"
Cover
Top edge turned on ⅛" iron wire
⅛ iron wire 1" long soldered
15"
Heavy Copper Angles
6"
3"
12"
½ pipe for connection to constant level bottle
3"
15"
FRONT
30"
SIDE
15"
BACK
PLAN
15"
14"
29"
Shelf to be made of 1/16 galvanized iron wire formed on a rim piece of ¼ galvanized iron wire. Size of mesh ½
Rubber stopper
Flexible rubber tube
Pinch Cock
Constant-Level Bottle
⅜" brass faucet
1¾"
2"
30"
TOP

Fig. 3.—Apparatus for Making Soundness Test of Cement.

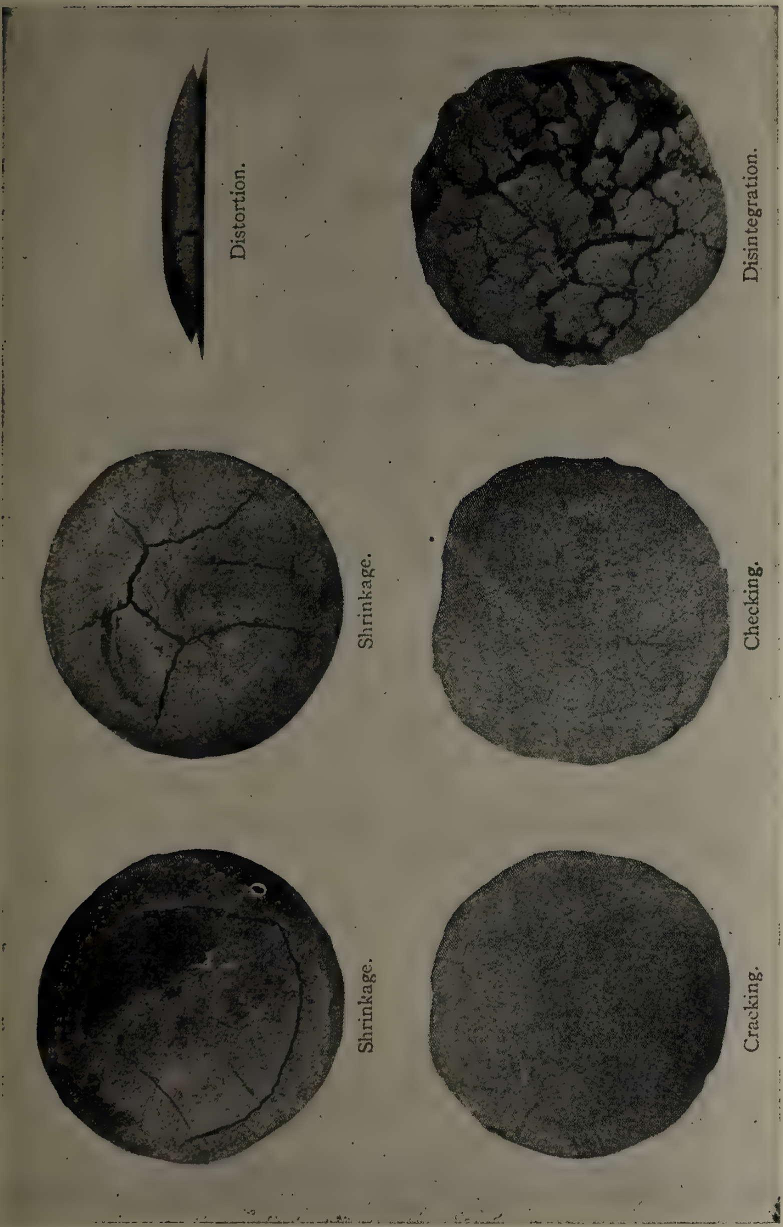
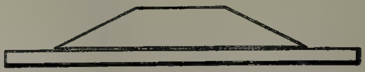
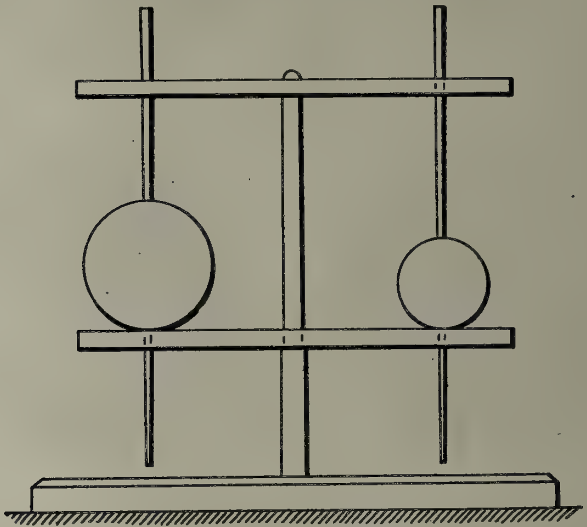


FIG. 4.—TYPICAL FAILURES IN SOUNDNESS TEST.

stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the temperature and humidity of the air, and its determination is therefore only approximate.



(*a*) Pat with Top Surface Flattened for Determining Time of Setting by Gillmore Method.



(*b*) Gillmore Needles.

Fig. 5.

Gillmore Needles.

49. The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in Fig. 5 (*b*).

Gillmore Method.

50. The time of setting shall be determined as follows: A pat of neat cement paste about 3 inches in diameter and ½-in. in thickness with a flat top (Fig. 5 (*a*)), mixed to a normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21 de-

grees Centigrade (70 degrees Fahrenheit). The cement shall be considered to have acquired its initial set when the pat will bear, without appreciable indentation, the Gillmore needle 1/12-in. in diameter, loaded to weigh ¼-lb. The final set has been acquired when the pat will bear without appreciable indentation the Gillmore needle 1/24-in. in diameter, loaded to weigh 1 lb. In making the test, the needles shall be held in a vertical position, and applied lightly to the surface of the pat.

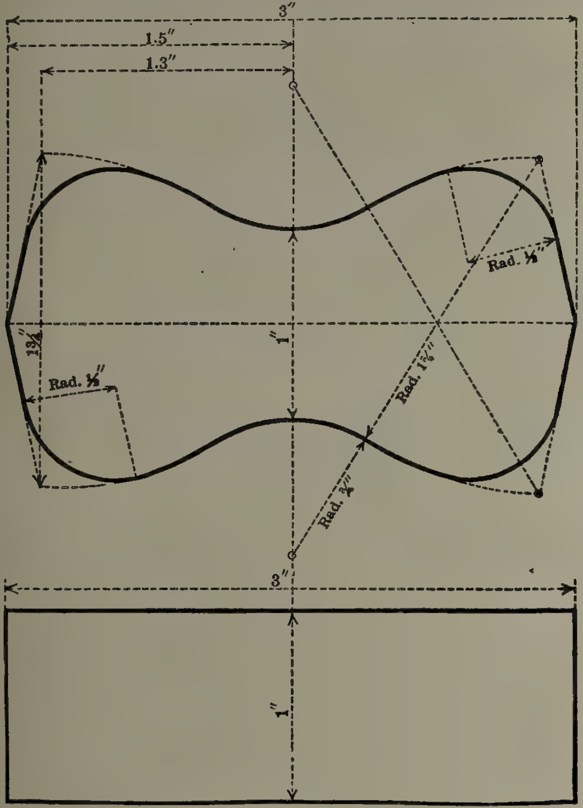


Fig. 6.—Details for Briquette.

(XIV) TENSION TESTS.

Form of Test Piece.

51. The form of test piece shown in Fig. 6 shall be used. The molds shall be made of non-corroding metal and have sufficient material in the sides to prevent spreading during molding. Gang molds when used shall be of the type shown in Fig. 7. Molds shall be wiped with an oily cloth before using.

Standard Sand.

52. The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained from the Ottawa Silica Company, at a cost of two cents per pound, f. o. b. cars, Ottawa, Ill.

53. This sand, having passed the No. 20 sieve, shall be considered standard when not more than 5 g. pass the No. 30 sieve after one minute continuous sieving of a 500-g. sample.

54. The sieves shall conform to the following specifications:

The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 in. and the average diameter shall not be outside the limits of 0.0160 and 0.0170 in.

The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31.5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 in. and the average diameter shall not be outside the limits 0.0105 to 0.115 in.

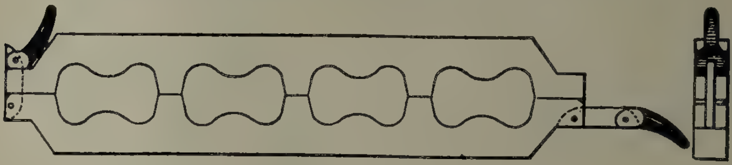


Fig. 7.—Gang Mold.

Molding.

55. Immediately after mixing, the standard mortar shall be placed in the molds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mold and smoothed off with a trowel; the trowel shall be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold shall then be turned over and the operation of heaping, thumbing and smoothing off repeated.

Testing.

56. Tests shall be made with any standard machine. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The briquettes shall be carefully centered and the load applied continuously at the rate of 600 lbs. per minute.

57. Testing machines should be frequently calibrated in order to determine their accuracy.

Faulty Briquettes.

58. Briquettes that are manifestly faulty, or which give strengths differing more than 15 per cent. from the average value of all test pieces

made from the same sample and broken at the same period, shall not be considered in determining the tensile strength.

(XV) STORAGE OF TEST PIECES.

Apparatus.

59. The moist closet may consist of a soapstone, slate, concrete or a wooden box lined with metal. If a wooden box is used, the interior should be covered with felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with non-absorbent shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

Methods.

60. Unless otherwise specified, all test pieces, immediately after molding, shall be placed in the moist closet for from 20 to 24 hours.

61. The briquettes shall be kept in molds on glass plates in the moist closet for at least 20 hours. After 24 hours in moist air the briquettes shall be immersed in clean water in storage tanks of non-corroding material.

62. The air and water shall be maintained as nearly as practicable at a temperature of 21 degrees Centigrade, 70 degrees Fahrenheit.

SPECIFICATIONS FOR NATURAL CEMENT.

Definition.

1. Natural cement is the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

(I) PHYSICAL PROPERTIES.

Fineness.

2. The residue on a standard No. 100 sieve shall not exceed 10 per cent., and on a standard No. 200 sieve shall not exceed 30 per cent. by weight.

Soundness.

3. Pats of neat cement about 3 in. in diameter, ½-in. thick at center, tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(*a*) A pat shall then be kept in air at normal temperature.

(*b*) Another pat shall be kept in water maintained as near 70 degrees Fahrenheit as practicable.

These pats shall be observed at intervals for at least 28 days, and, to satisfactorily pass the tests, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

Time of Setting.

4. The cement shall not develop initial set in less than 10 minutes, using Vicat needle. Final set shall be attained in not less than 30 minutes nor more than 3 hours, using the Vicat needle.

Tensile Strength.

5. The minimum requirements for tensile strength for briquettes 1 sq. in. in cross-section shall be as follows, and the cement shall show no retrogression in strength within the periods specified:

Neat Cement.

Age.	*Strength.*
24 hours in moist air	75 lbs.
7 days (1 day in moist air, 6 days in water)	150 lbs.
28 days (1 day in moist air, 27 days in water)	250 lbs.

One Part Cement, Three Parts Standard Ottawa Sand.

Age.	*Strength.*
7 days (1 day in moist air, 6 days in water)	50 lbs.
28 days (1 day in moist air, 27 days in water)	125 lbs.

(II) PACKAGES, MARKING AND STORAGE.

Packages and Marking.

6. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon. A bag shall contain 94 lbs. net. A barrel shall contain 282 lbs. net.

Storage.

7. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building, which will protect the cement from dampness.

(III) INSPECTION.

Inspection.

8. (*a*) Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test.

(*b*) The cement shall be tested in accordance with the methods contained in the Standard Specifications and Tests for Portland Cement.

(IV) REJECTION.

Rejection.

9. The cement may be rejected if it fails to meet any of the requirements of these specifications.

10. Cement failing to meet the 7-day requirements may be held awaiting the results of the 28-day tests before rejection.

COMMITTEE X.

SIGNALS AND INTERLOCKING.

*LIST OF THE FINDINGS, CONCLUSIONS, STANDARDS AND SPECIFICATIONS ADDED TO THE MANUAL OF THE RAILWAY SIGNAL ASSOCIATION IN 1916.

TEXT.

- Battery, Storage:
  - Charging equipment.
  - Composite type, stationary, for signaling (Specifications).
  - Lead type, portable for signaling (Specifications).
- Cables:
  - Aerial aluminum steel reinforced cable (Specifications).
- Conduits:
  - Installation of Fiber and Metal Systems (Specifications).
- Interlocking:
  - Electro mechanical (Specifications).
- Wires and Cables:
  - Definitions of principal terms.
  - Aerial aluminum steel reinforced cable (Specifications).

DRAWINGS.

Carriers, transverse pipe	1073
Compensator, link	1017
Crank stand, two-way separate pin horizontal	1393
Elevators, battery	1227
Foundation, ground mast bottom mechanism, single or double case	1259
Jaws, with tang ends	1360
Lug, one-inch pipe	1017
Masts, Signal:	
Adapter base for ground mast bottom mechanism	1387
Details and assembly	1035
Signals:	
Semaphore bearings, mechanical	1082
Details and assembly for	1194
Signal, two-way single lamp:	
Semaphore spectacle design "C" for	1235
Crank bearings and clamps for	1355
Double spectacle bearings and lamp bracket for	1356
Ladder, details and assembly for	[illegible]

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*Adopted, Vol. 18, 1917, pp. 88, 89, 1439.

Stands:
  Crank, two-way separate pin horizontal........................1393
  Low target 1399
Switch:
  Adjustment, details 1390
  Adjustment, non-insulated 1391
  Adjustment, insulated 1392

*REQUISITES OF SWITCH INDICATORS.

PURPOSES.

1. Switch indicators are recognized as an adjunct of the automatic block system. They may be arranged to indicate one or more of the following:

1-a. Whether or not a train is approaching.

1-b. Whether or not that portion of the block between the switch and the next Home Block Signal in advance is clear.

1-c. Whether or not the next Home Block Signal in the direction of approaching trains is at stop.

In the Standard Code of the American Railway Association, switch indicators are placed among the adjuncts of the automatic block system: "(C) Indicators at main track switches." It is recommended that the purposes for which switch indicators may be used, and their location and control, be specified by amplification of adjunct (C) and the addition of requisites of installation, as follows:

(C) Indicators at main track switches to indicate, on roads of two or more tracks, one or more of the following:

1-a. Whether or not a train is approaching.

1-b. Whether or not that portion of the block between the switch and the next Home Block Signal in advance is clear.

1-c. Whether or not the next Home Block Signal in the direction of approaching trains is at stop.

2. In a system equipped with switch indicators, indicators are unnecessary, and may therefore be omitted, at certain switches where signals are so located and controlled that the indications which would be given by the switch indicators can be obtained from the aspects of the signals.

REQUISITES OF INSTALLATION.

1. Switch indicators located preferably:

1-a. At main track switches connecting with tracks on which trains may clear main track and in which either there are no derails or diverging switches, or the derails or diverging switches are connected with the main-track switches.

1-b. At independently operated derails or diverging switches in tracks on which trains may clear main tracks.

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*Adopted, Vol. 18, 1917, pp. 89, 91, 1441.

1-c. At points from which switches of crossovers between main tracks are operated, or locked, where both switches are operated or locked from the same point.

1-d. At independently operated switches of crossovers between main tracks, the indicator at the switch in one track operated in connection with the other track.

2. A switch indicator for each direction where indications relating to traffic in both directions on the same track are to be given.

3. Switch indicators that cannot be identified by their locations, marked with the designations of the tracks or the directions of traffic in connection with which they are operated.

4-a. The connections of switch indicators used to indicate whether or not a train is approaching, so arranged that an indicator will indicate the approach of a train that has reached a point at least such a distance in the rear of the second block signal in the direction of approaching trains, that if the switch is thrown at the moment when a train reaches that point, the Caution-signal will be displayed in time to be observed by the engineman, and will continue so to indicate until the train passes the Home Block Signal in the rear of the switch or, approximately, the clearance point of the switch when the switch is more than.........feet in advance of the Home Block Signal. The distance of the point at which the approach of a train is first indicated will be determined in each case by the grade, speed of trains, view of the signal or other local conditions.

4-b. Equivalent control of signals certain aspects of which serve, in lieu of switch indicators, to indicate whether or not a train is approaching.

COMMITTEE XIII.

WATER SERVICE.

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*QUALITY OF WATER, METHODS OF TREATMENT AND RESULTS OBTAINED THEREFROM.

Amendments:

(3) Hard water can be softened by treatment with chemicals.

(7) There are two general types of water softeners, the continuous and the intermittent, differing widely in their mechanical details.

(12) The benefits derived from water softening plants are: Fewer boiler failures; longer life of flues and fire boxes; reduced cost of labor for cleaning, washing and repairing boilers; increased locomotive mileage between shoppings; decreased number of locomotives required; reduction of overtime and delays; reduced fuel consumption; expedition of transportation; increased transportation capacity.

EFFICIENCY OF WATER SOFTENERS.

(*a*) DESIGN AND INSTALLATION.

Amendments:

(2) Generally, installation of softening plants should follow a plan based on the operating division. Usually, the complete equipment of one division will give better results than an equal number of plants scattered over a number of divisions.

(3) Whether or not the water can be successfully treated should be determined. Water sometimes contains solids of such character, combination and quantity that the water is unfit for use after treatment.

(4) The plant should have adequate capacity. Probable increase in water consumption should be anticipated.

(5) The mechanical apparatus should be simple in construction and operation, stable in adjustment and should accurately and uniformly introduce the chemicals into the water in necessary proportion.

(*b*) OPERATION, MAINTENANCE AND SUPERVISION.

(3) Where consumption of water is in excess of the effective capacity of the plant, the use of untreated, milky water should be avoided by the use of raw water to such an extent as to give ample time for the proper treatment of all water that passes through the softener. The exception to this rule is the case of water which is being treated for corrosive properties. Such water should not be used raw if it can be avoided.

(Omit clause (4) and number former (5), (4).

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*Adopted, Vol. 18, 1917, pp. 543, 1451.

(4) The reagents, as nearly as practicable, should be chemically pure.

(*c*) CAPACITY OF WATER SOFTENERS.

(3) In continuous softeners, the capacity of the tank reserved for treatment and sedimentation should be not less than three to four times the hourly capacity of the plant, depending on the temperature of the water, low temperature requiring the larger capacity.

One Pump Only Is Necessary:

(*c*) Where water is pumped to the settling and storage tanks and the daily rate at which the water may be delivered is not less than twice the daily capacity of the plant.

Two Pumps Are Necessary:

(*d*) When deep wells furnish the supply and the water must be pumped from settling tanks to storage tanks.

(*e*) Where water is pumped to settling and storage tanks and the daily rate at which the water may be delivered is less than twice the daily capacity of the plant.

In all the foregoing cases excepting (*c*) the capacity of each pump or battery of pumps should be not less than the capacity of the softener. If the pumps used to transfer the treated water are of larger capacity, reducing the time required to transfer the treated water to storage tanks, the settling tank capacity may be reduced.

In case (*c*) the pump handles the water twice in transferring it from the supply to the storage tank, consequently its daily capacity should be not less than twice the daily capacity of the softener.

RELATIVE ECONOMY OF DIFFERENT TYPES OF SOFTENERS.

Amendments:

(*c*) Current repairs.

(*d*) Increased cost of operating the water station due to additional labor and fuel required for the treatment.

FOAMING AND PRIMING.

Amendments:

Omit fifth paragraph, beginning "Aside from occasional complete change," etc.

GENERAL PRINCIPLES OF WATER SUPPLY SERVICE.

SUPPLY—SOURCE.

Amendments:

Where water of suitable quality and in sufficient quantity can be purchased at a reasonable cost, it is recommended above all other sources.

Springs should be carefully investigated to determine their yield. The possibility or probability of their pollution and the quantity of water likely to be required in the future should be considered. If the daily flow of springs is not largely in excess of the daily quantity required, a reservoir should be constructed.

Lakes, natural ponds, creeks, or rivers require special investigation in each case. The points to be considered are quantity, quality—as regards chemical impurities and amount of sediment carried—future pollution and riparian rights. The style of intake will depend on local conditions entirely; no definite rule can be given.

In unproved ground, dug well construction should be preceded by test borings to reveal the strata to be penetrated. The character of the strata largely determines the size of the well and the kind of construction necessary.

The pipe system of driven or drilled wells shown in Fig. 2, being capable of wide extension, is satisfactory for underground water when found at shallow depths easily reached by the system.

Artesian deep wells, where obtainable, are a satisfactory source; however, their flow is liable to constant decrease and finally cease.

Deep wells that require pumping usually cost more for maintenance and operation than other sources, are generally for that reason undesirable, but their disadvantages are often compensated by the excellence and security from pollution of the water yielded by them.

Chemical analysis should be made of water from present and prospective sources and the cost of treatment, if required, determined as hereinbefore indicated and outlined.

COMMITTEE XVII.

WOOD PRESERVATION.

*SPECIFICATIONS FOR CREOSOTE OIL ANALYSES.

(1) WATER.

Apparatus.

Copper still shown in Fig. 1 and Fig. 2 below.

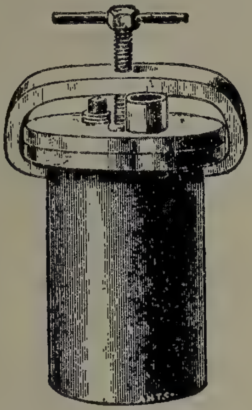

FIG. 1.—COPPER STILL.

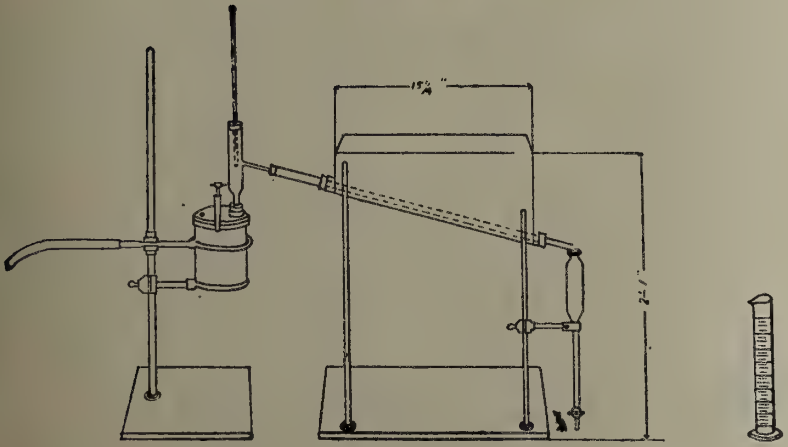

FIG. 2.—COPPER STILL SET UP.

Method.

When any measurable amount of water is present in the distillate below 210 degrees, on testing in accordance with Section 4, Distillation, the oil and water in this fraction shall be separated, if possible, and measured separately. If more than 2 per cent. of water is present, or if the water is apparently present to an extent in excess of 2 per cent., but an accurate separation is impossible, the percentage of water present shall be determined by the following method, and the water-free oil so obtained shall be used in distillation test, as described under Section 4.

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*Adopted, Vol. 18, 1917, pp. 1262, 1577.

Measure 200 cc. of oil in graduated cylinder, and pour into copper still (Figs. 1 and 2), allowing the cylinder to drain into the still for several minutes. Attach lid and clamp, using a paper gasket slightly wet with oil around the flange of the still. Apply heat by means of the ring burner, which should be placed just above the level of the oil in the still at the beginning of the test, and gradually lowered when most of the water has distilled over. Continue the distillation until the vapor temperature indicated by the thermometer with the bulb opposite the offtake of the connecting tube reaches 205 degrees Centigrade. Collect distillate in separatory funnel.

When the distillation is completed, and a clear separation of water and oil in the funnel has taken place, the water is read by volume and drawn off, and whatever light oil has distilled over with the water is then returned to the oil in the still. The dehydrated oil from the still is then taken for distillation, described in Section 4, Distillation.

(2) INSOLUBLE IN BENZOL.

Apparatus.

(a) Extractor may be of the form shown in Fig. 3, or any similar form in which the oil is subjected to direct washing by the boiling vapors of the solvent.

(b) Filtering medium may be either two thicknesses of S. & S. No. 575 or Whatman No. 5 hardened filter paper, 15 cm. in diameter, arranged in cup-shape by folding symmetrically; or alundum thimbles, flat bottom, 30x80 RA. 98. If filter papers are used, prior to using they shall be soaked in benzol to remove grease, dried in a steam oven and kept in a dessicator until ready to be used. The filter-paper cup may be suspended in the extractor flask by a wire basket hung from two small hooks on the under surface of the metal cover of the flask.

If the alundum thimble is used, it may be supported by making two perforations in the top of the thimble, and suspending from the cover by German silver or platinum wires.

Method.

Weigh 10 grams of dry oil in 100 cc. beaker. Add about 50 cc. of pure benzol, and transfer at once to the filter cup. The filter cup or thimble is previously weighed, and the paper cup shall always be kept in a weighing bottle until ready for use. Wash out the beaker with benzol, passing all washings through the filter cup, and place the latter at once in the extraction apparatus.

Extractor shall contain a suitable quantity of pure benzol. Sufficient heat to boil the solvent shall be provided by means of an electric heater or a steam bath.

Continue the extraction until the descending solvent is practically colorless, and remove the filter cup and dry in steam oven until all solvent is driven off; cool in dessicator and weigh. The balance used for this purpose should be accurate to within 0.5 mg.

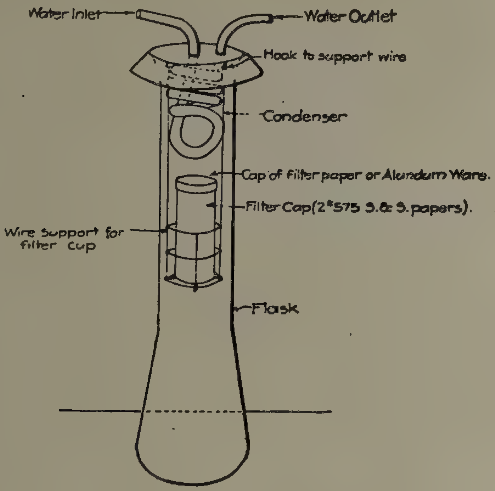
Water Inlet
Water Outlet
Hook to support wire
Condenser
Cap of filter paper or Alundum Ware.
Filter Cap (2 #575 S.& S. papers).
Wire Support for filter cup
Flask

FIG. 3.—EXTRACTOR.

(3) SPECIFIC GRAVITY.

Apparatus.

(a) Hydrometer shall be of the form and dimensions shown in Fig. 4. It shall be standardized at 15.5 degrees Centigrade. A set of two with ranges 1.00 to 1.08 and 1.07 to 1.15 will suffice.

(b) Cylinder shall be of the form and dimensions shown in Fig. 5.

Method.

The oil shall be brought to a temperature of 38 degrees Centigrade (100 degrees Fahrenheit), and the determination shall be made at that temperature unless the oil is not entirely liquid at 38 degrees Centigrade. In case the oil requires to be brought to a higher temperature than 38 degrees in order to render it completely fluid, it shall be tested at the lowest temperature at which it is completely fluid, and a correction made by adding 0.0008 to the observed specific gravity for each degree Centigrade above 38 degrees Centigrade at which the test is made. This correction does not apply with equal accuracy to all oils, but serious error, due to its use, will be avoided if the foregoing precaution is observed, with respect to avoiding unnecessarily high temperature.

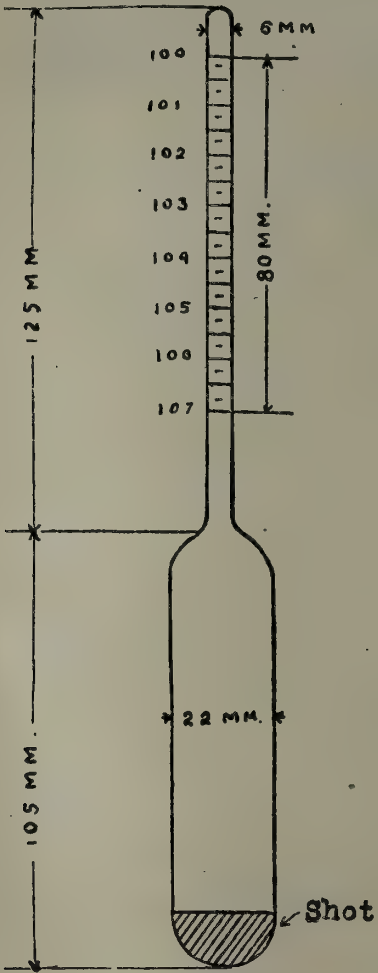

Fig. 4. Hydrometer.

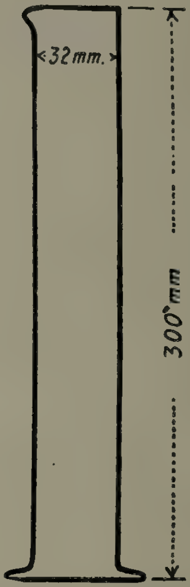

Fig. 5. Specific Gravity Cylinder.

(4) Distillation.

Apparatus.

(a) Retort shall be a tabulated glass retort of the usual form with a capacity of 250 to 290 cc. The capacity shall be measured by placing the retort with the bottom of the bulb and the end of the offtake in the same horizontal plane, and pouring water into the bulb through the tubulature until it overflows the offtake. The amount remaining in the bulb shall be considered its capacity (Fig. 6).

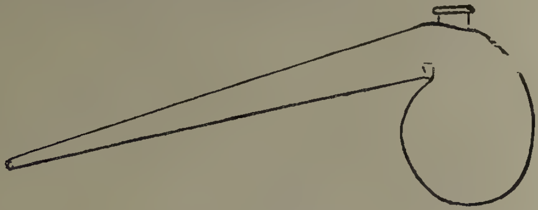

FIG. 6.—RETORT.

(b) Condenser tube of any suitable form of glass may be used; a convenient one is shown in Fig. 7.

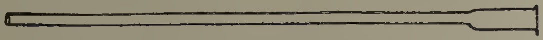

FIG. 7.—CONDENSER TUBE.

(c) Shield of asbestos as shown in Fig. 8 shall be used to protect the retort from air currents, and to prevent radiation. This may be covered with galvanized iron, as such an arrangement is more convenient and more permanent.

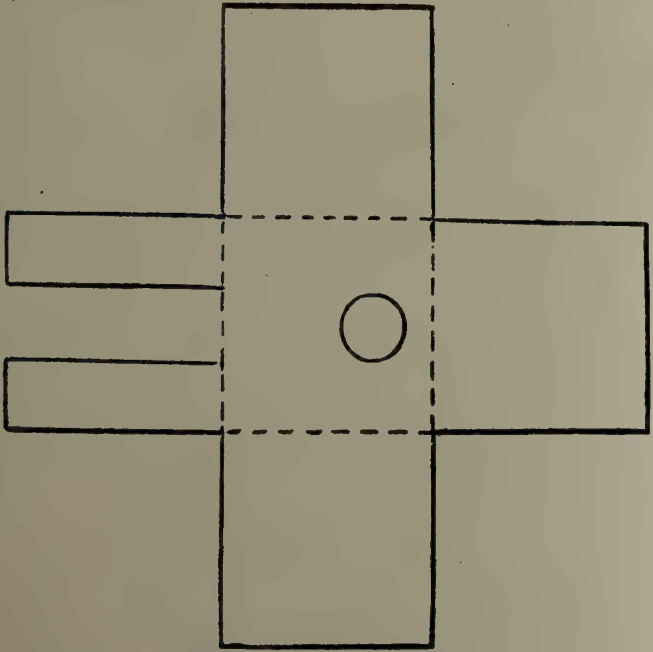

FIG. 8. ASBESTOS SHIELD.

(d) Receivers (Erlenmeyer flask) of 50 to 100 cc. capacity are most convenient form.

(e) Thermometer shall be made of resistance glass of a quality equivalent to suitable grades of Jena or Corning make. It shall be thoroughly annealed. It shall be filled above the mercury with inert gas which will not act chemically on or contaminate the mercury. The pressure of the gas shall be sufficient to prevent separation of the mercury column at all temperatures of the scale. There shall be a reservoir above the final graduation large enough so that the pressure will not become excessive at the highest temperature.

The thermometer shall be finished at the top with a small glass ring or button suitable for attaching a tag. Each thermometer shall have for identification the maker's name, a serial number and the letters "A. S. T. M. Distillation."

The thermometer shall be graduated from 0 to 400 degrees Centigrade at intervals of 1 degree Centigrade. Every fifth graduation shall be longer than the intermediate ones, and every tenth graduation beginning at zero shall be numbered. The graduation marks and numbers shall be clear cut and distinct.

The thermometer shall conform to the following dimensions:

Total length, mm., 385 maximum.

Diameter of stem, mm., 7; tolerance, 0.5.

Diameter of bulb, mm., 5 minimum, and shall not exceed that of the stem.

Length of bulb, mm., 12.5; tolerance, 2.5.

Distance 0 degrees to bottom of bulb, 30; tolerance, 5.

Distance 0 degrees to 400 degrees Centigrade, 295; tolerance, 10.

The accuracy of the thermometer when delivered to the purchaser shall be such that when tested at full immersion the maximum error from 0 degrees to 200 degrees Centigrade shall not exceed 0.5 degrees; 200 degrees to 300 degrees Centigrade it shall not exceed 1 degree Centigrade; 300 degrees to 375 degrees Centigrade, it shall not exceed 1.5 degrees Centigrade.

The sensitiveness of the thermometer shall be such that when cooled to a temperature of 74 degrees Centigrade below the boiling point of water at the barometric pressure at the time of the test and plunged into free flow of steam, the meniscus shall pass the point 10 degrees Centigrade below the boiling point of water in not more than six seconds.

The retort shall be supported on a tripod or rings over two sheets of 20-mesh gauze, 6 in. square. It shall be connected to the condenser tube by a tight cork joint. The thermometer shall be inserted through a cork in the tubulature with the bottom of the bulb ½-inch from the surface of the oil in the retort. The exact location of the thermometer bulb shall be determined by placing a vertical rule graduated in divisions not exceeding 1/16 in. back of the retort when the latter is in position for the test, and sighting the level of the liquid and the point for the bottom of the thermometer bulb. The distance from the bulb of the thermometer to the outlet end of the condenser tube shall be not more than 24 nor less than 20 in. The burner shall be protected from draughts by a suitable shield or chimney (Fig. 9).

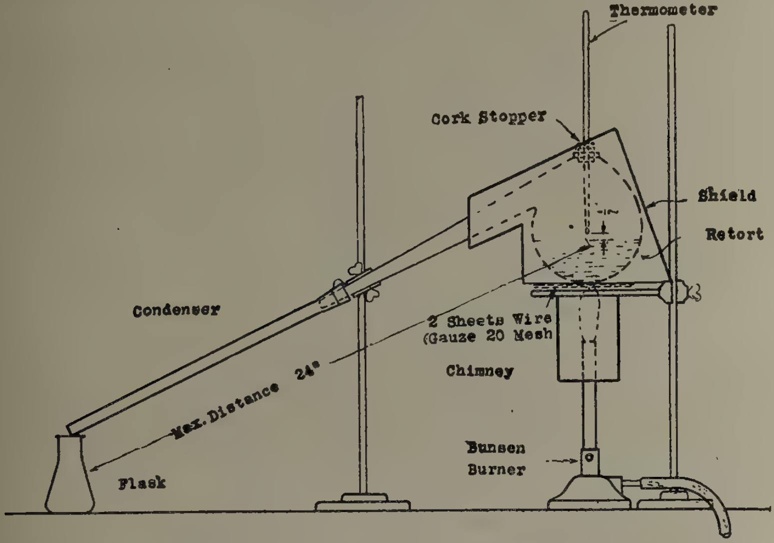

Fig. 9.—Distillation Apparatus Set Up.

Method.

Exactly 100 grams of oil shall be weighed into the retorts, the apparatus assembled, and heat applied. The distillation shall be conducted at the rate of at least one drop and not more than two drops per second, and the distillate collected in weighed receivers. The condenser tube shall be warmed whenever necessary to prevent accumulation of solid distillates. Fractions shall be collected at the following points: 210 degrees, 235 degrees, 270 degrees, 315 degrees, and 355 degrees Centigrade.

The receivers shall be changed as the mercury passes the dividing temperature for each fraction. When the temperature reaches 355 degrees, the flame shall be removed from the retort, and any oil which has condensed in the offtake shall be drained in the 355-degree fraction.

The residue shall remain in the retort with the cork and the thermometer in position until no vapors are visible; it shall then be weighed.

For weighing the receivers and fractions, a balance accurate to at least 0.05 g. shall be used.

During the progress of the distillation the thermometer shall remain in its original position. No correction shall be made for the emergent stem of the thermometer.

When any measurable amount of water is present in the distillate, it shall be separated as nearly as possible and reported separately, all results being calculated on a basis of dry oil. When more than 2 per cent. of water is present, water-free oil shall be obtained by separately distilling a larger quantity of oil, returning to the oil any oil carried over with the water, and using dried oil for final distillation. (See Section 1, Water.)

(5) SPECIFIC GRAVITY OF FRACTIONS.

As specific gravity is an absolute physical determination, any recognized method which can be applied to the quantity and quality of material at hand to be tested must be considered satisfactory. The following methods are recommended by the Committee as convenient and accurate means for the relatively small amounts of oil available in determining gravity of fractions to be tested.

LIQUID FRACTIONS.

Apparatus.

Westphal balance.

Method.

If the fraction to be tested is liquid at a temperature not exceeding 60 degrees Centigrade, the Westphal balance can be used with convenience and rapidity. A special type of Westphal balance is obtainable, designed for testing very small quantities. However, the ordinary type Westphal balance can be adapted to testing small fractions by the use of a special plummet. This can readily be made in the laboratory from a piece of ordinary glass tubing 7 mm., outside diameter, sealed at the end, and melting into the glass where sealed a short platinum wire.

After cooling place 9 to 10 grams of mercury in the tube, making a column 35 to 40 mm. high. Seal off the tube within 20 mm. of the top of the mercury column with blowpipe flame. The plummet should have a length of about 55 to 60 mm. over all, and should weigh between 10 and 12 grams.

SOLID AND SEMI-SOLID FRACTIONS.

Apparatus.

Special platinum or nickel pan as shown in Fig. 10.

Method.

For the determination of fractions that are solid or semi-solid and cannot readily be liquefied at a temperature not exceeding 60 degrees Centigrade, a weighing pan constructed of platinum or nickel (Fig. 10) may be used.

A pan of convenient dimensions is 20 mm. diameter at the base and 25 mm. diameter at the top, and about 12 mm. deep. It is made of platinum and supported by three platinum wires 1 mm. in diameter, and has a total weight of about 7 grams.

Solid or semi-solid fractions of oil can be rapidly and accurately tested in this apparatus by the usual method of weighing in air and in water. The usual precaution, of igniting the pan before use, avoiding the enclosure of air or water in the sample, should be observed.

NOTE.—The method for liquid fractions is usually applicable to the fractions 235 to 315 degrees Centigrade and the method for solid and semi-solid fractions to the fraction 315 to 355 degrees Centigrade.

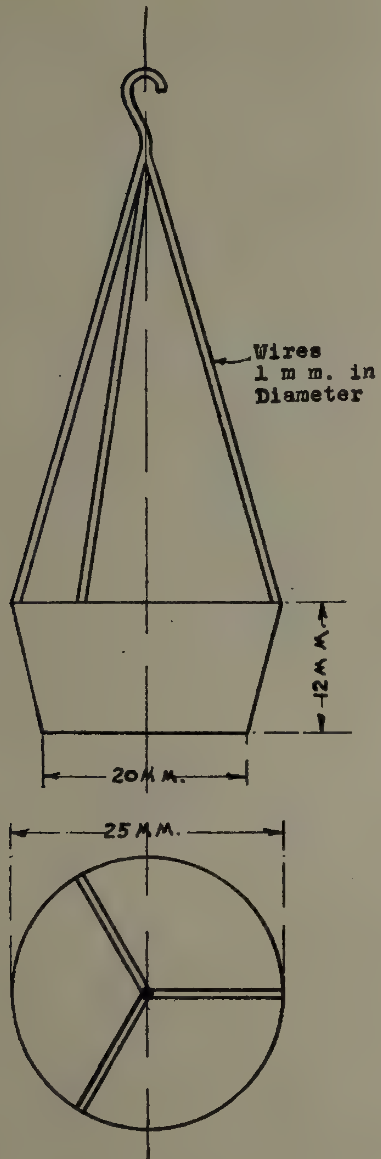

FIG. 10.—WEIGHING PAN.

*SAMPLING OF CREOSOTE OIL FOR WATER CONTENT.

1. For the accurate determination of water in a tank car of creosote, a system of sampling from several zones in a car is necessary. These zones must represent definitely calculated areas throughout the entire depth of the car. There must be at least three zones, the top, the middle and the bottom of the car. For the most definite determinations zones one foot deep are to be preferred.

2. For calculating the percentage of water found in any zone in relation to its proportion to the entire car, the correction factor indicated on diagram, Fig. 1, should be used. The actual percentage of water found in any zone does not correctly represent the real percentage, because the number of gallons found in the different zones differ because of the shape of the tank car. The percentage of water found in each zone should be multiplied by the figure at the right-hand side of the diagram representing the relation of this zone to the entire car. In other words, take the diameter of the car, as shown by the figures at the base of the diagram, run up on the vertical line to the zone line, and where this point crosses the horizontal line note the figure at the left-hand side of the diagram, which will express the percentage relation. The sum of the results obtained for this calculation for the samples from the different zones represents the total percentage of water in the car.

3. The cross-section tube frequently used for taking samples from tank cars is of little value. It disregards the fundamental principle of zone sampling, in that it takes no account of the proportionate value of the sample taken with reference to the whole car. It, furthermore, cannot be used in connection with zone sampling without much additional computation.

4. The so-called thief (1915 Proceedings, American Railway Engineering Association, Vol. 16, page 831) has been found incorrect in theory, and the results obtained therewith confirm this.

5. The taking of a dipper or bucket sample from the running stream of cars while discharging does not give reliable results, and this method should not be used.

6. The bottle method, meaning the use of a small stoppered vessel from which the cork can be withdrawn at any desired level, is a convenient apparatus for taking zone samples. Its disadvantage lies in the fact that escaping air, after the withdrawal of the cork, tends to disturb the surrounding oil. and therefore gives an incorrect sample.

7. For obtaining zone samples an apparatus of the type illustrated in Figs. 3 and 4 should be used. This apparatus consists of a brass cylinder with a pointed, perforated bottom. The holes in the bottom are closed by means of a spring valve, which can be opened by means of a wire extending along the extended stem attached to the cylinder. This stem is made in several sections, so that it can be used at any depth. The stem is calibrated in feet and inches, thus facilitating the zone sampling.

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*Adopted Vol. 18, 1917, pp. 1271, 1579.

8. For ordinary purposes the taking of three zone samples, that is from the top, the middle and the bottom of a car, by means of the apparatus described in the preceding paragraph, is recommended.

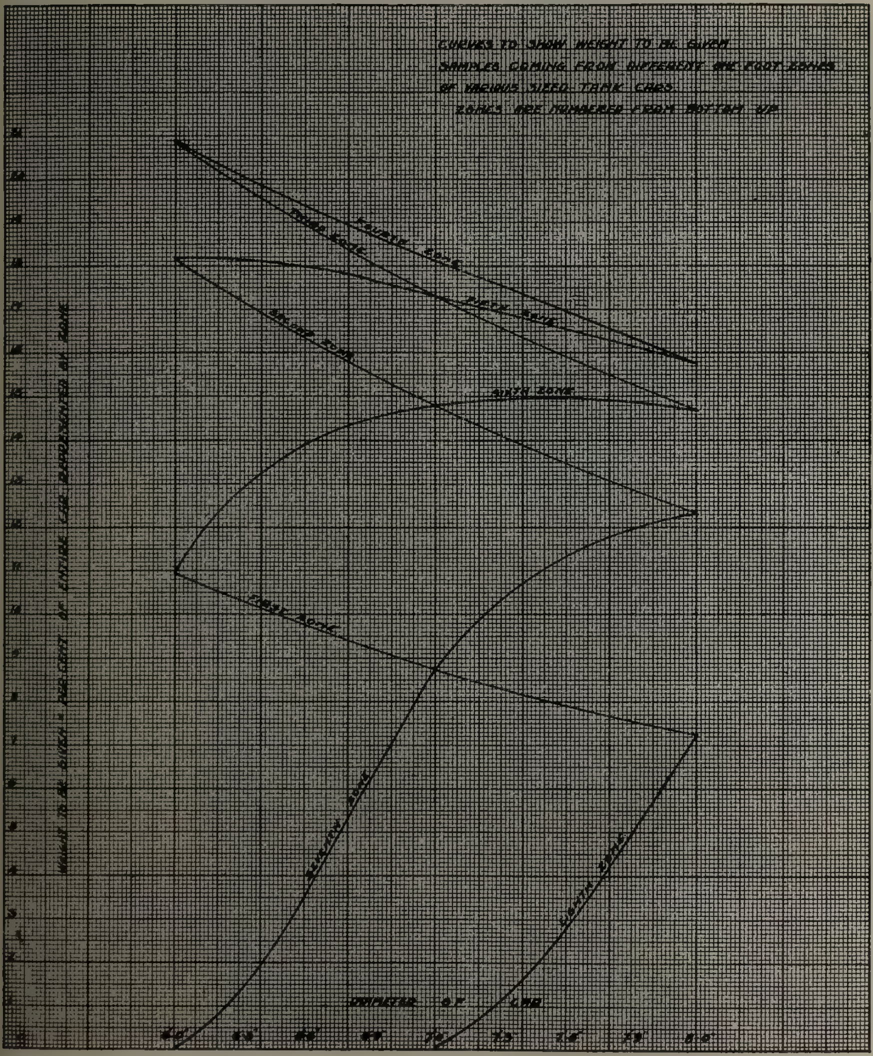

FIG. 1.

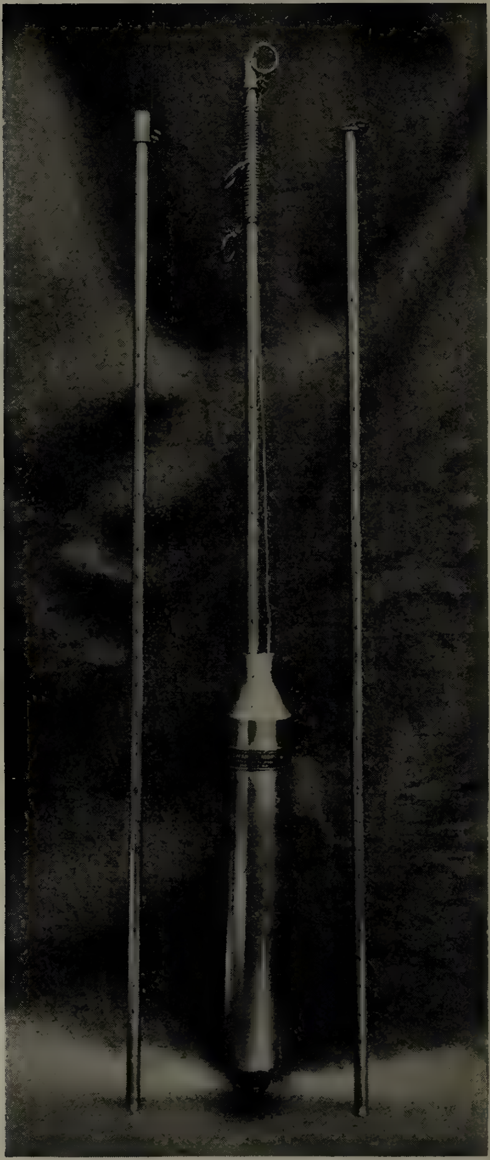

Fig. 2. Apparatus for Obtaining Zone Samples.

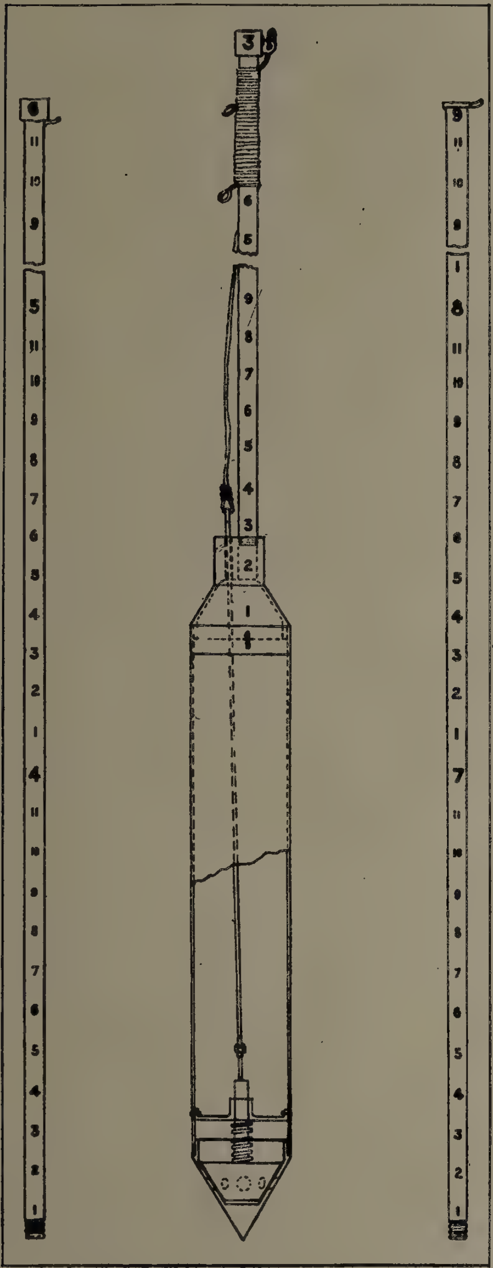

FIG. 3. DETAILS OF ZONE SAMPLING APPARATUS.

The detail drawing of the Zone Sampling Apparatus is published through the courtesy of the makers, Messrs. Howard & Morse, Brooklyn, N. Y., who designed the apparatus in accordance with suggestions of your Committee.

DESIGN OF DOCKS AND WHARVES.

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To clear the misunderstanding from our subject, "Docks and Wharves," the word "dock" being used frequently to mean a wharf or pier, various authorities are here quoted to show the distinction.

"Haswell: 'Dock,' in Marine Architecture; an enclosure in a harbor or shore of a river, for the reception, repair or security of vessels or timber. It may be wholly or only partially enclosed. When applied to a single pier or jetty, it is misapplication."

"'Pier,' in Marine Architecture; a mole or jetty, projecting into a river or sea, to protect vessels from the sea, or for convenience of their lading. Erroneously termed a Dock." Thus Haswell early noted the confusion of ideas and attempted to correct them.

"Trautwine: 'Dock,' an artificial enclosure either partial or total, in which ships and other vessels are placed for being loaded or unloaded or repaired. The first is a wet dock, the last a dry one."

"'Wharf,' a level space upon which vessels lying along its side can discharge their cargoes, or from which they can receive them."

"Albert I. Frye: A Dock is an artificial receiving basin for water craft—for loading, unloading, repairing, etc. It need not necessarily be 'closed'." A common form of dock is the "open" basin between adjacent wharves or piers; thus, we speak of "docking" a vessel, or bringing her up alongside one of the wharves or piers.

Where the rise and fall of the tide is excessive and would interfere with loading and unloading, these are provided with gates which are opened only at full tide. It is but a step from the common "closed" dock to the "Graving Dock."

"A Wharf is essentially a platform structure projecting outward from the shore, and alongside of which watercraft may be moored for the exchange of freight or passengers."

"The term 'Quay' is applied distinctly to a wharf which skirts the shore, and runs about parallel with, and extends to no great distance beyond the shore line."

"A Pier, on the other hand, is a wharf which projects outward from the shore a considerable distance; is supported usually on piles and (foundation) piers; and hence has 'open waterways' beneath the platforms."

"A Ferry Slip is a dock for a ferry boat."

"A Graving Dock (commonly called a Dry-Dock) is an excavated basin into which a vessel can be floated, the gates closed, the water forced out and the hull exposed for inspection, repairs, cleaning, painting, etc."

"A Floating Dock (commonly called a Floating Dry-Dock) is what its name implies and need not be defined."

Conception.

By conception of a dock and wharf we mean the act of the primary creator of the general idea who, as a railroad president, corporation director or property owner, conceives or puts together the plan of constructing and operating a dock and wharf, building his thought from a mass of separate ideas, business conditions, laws and physical conditions. He starts from a nebulous mass of information with or without few factors of evaluation of the numerous parts and directs the project into engineering channels, from which comes the final development and structure. The Engineer, because of the knowledge he possesses of the properties and use of materials, their costs and relative economies, may even be called into or delegated to solve the problem in its conception as well as develop the plan.

Therefore the problem of the conception of the plan is outlined here before taking up the factors of design.

If it were possible to give each factor of design a value the problem might be reduced to a mathematical basis, but the factors are variable and can only be expressed in general terms until a definite problem is studied.

In conceiving the general plan or scheme of a dock, wharf or waterfront improvement, the character of the service to be rendered or the mission of the completed property is of first importance. A dock and wharf is a means to an end. Except as the means determines the operating cost, the choice of the means is of less importance than the accomplishment of the ends. That plan which accomplishes the end with the lowest cost per year is the most economical. We must include in the cost per year charges which will secure all original invested capital. Each kind of business or service has its own peculiar requirements which call for appropriate qualities in the character of the dock and wharf.

Dock.

By the definition given above, the dock being the water basin adjacent to the wharf and serving the purpose of giving approach to the wharf for appropriate vessels, is of fewer and simpler details. It partakes of the qualities of any sea road, that is, sufficient room to maneuver the boats with ease and dispatch, including boats of the present size and future increased size, sufficient frontage on wharf to accommodate the required number of vessels with depth to float loaded vessels of the present draft and future design.

Consideration must be given to allowing space enough for maintenance and dredging operations if the conditions are liable to cause changes in the depth of water.

The vessels inside the dock should not be unnecessarily exposed to rough water, and if possible the plan should be such as to secure favorable conditions at the entrance for boats during rough weather and various phases of the tide.

In some cases the dock may be constructed on line of two adjacent properties of different ownership, the dock area being chosen sufficient to serve both properties. The total area thus devoted to water surface may be less than the area required if both parties were to build separate docks. Dock property, which includes the land under the water, available for construction of both dock and wharf, has risen in value in recent years and economy in the plan which will minimize the area wasted in waterway is greatly to be desired. Community developments of dock property are very important. The United States Government has spent large sums of money in developing harbors and approaches thereto and will continue to do so. This cost is borne indirectly by all and economy in use of the frontages on these harbors will lessen the total amount required to be spent on harbor development, besides producing the greatest returns to each individual property.

Sometimes the dock work is reduced to a minimum because the necessary service is secured by a pier run out into deep water.

Wharf.

The general scheme will often be started with limitations of property available either because of prohibitive cost or the finished development of adjoining property by other owners. The shape of parcels of water front property is more liable to be irregular than regular, sometimes approaching the square, at other times a long strip between other strips. Sometimes when the shape is suitable, the approach is unsatisfactory because of developments of industries and surrounding communities. The facility of approach with the railroad tracks, complications of manufacturing and improved properties, general natural layout of the ground over which the approaching railroads are to operate, may materially alter the general conception. These predetermined conditions may force unsatisfactory arrangements, but care must be given to eliminate constrictions at any point on the approach which will develop neck-of-the-bottle effects and limit the full use of the property.

Change in value of real estate and dock property should be considered. Property may become too valuable for use as originally intended and require a change to justify the interest charge which is always to be governed by present values.

Having in mind the property to be used, the possible approaches to it and the nature of service to be rendered by the developed work, a further discussion of the determining factors is given to show how wide the divergence in conception may go. With many factors, some natural and unchangeable, some man-made and changeable, some business and economic which are man- or community-made, but of such nature as not to be altered to any large degree, each person who has the duty of judging will put a different valuation and develop a different conception. Each factor has a different valuation for a short life structure than for a long time development.

The character of the service to be rendered is of prime importance. The effort should be to get the best degree of service because the welfare of the business depends upon the quality. Success in service promotes success in business.

Failure to select a layout which gives the best service will surely lead to a revamping, a process which nearly always entails loss of capital.

Passenger Service.

If the plant is to accommodate passenger service, its arrangement as to safety and convenience should be given careful attention. Ease of transferring passengers from trains or from land approaches to floating equipment, ample room for allowing rapid and safe movements, are factors which will largely control the general conception, as will also the passenger service whether ocean-going, long voyages or short-voyage ferry service. The character and number of passengers handled influence the valuation to be given to convenience and comfort. Passenger service coming in contact with human and psychological factors requires a higher state of perfection, dependability and safety, especially so if in competition.

Freight Service.

If the service is that of handling freight there are even more factors arising which will influence the arrangement. To handle miscellaneous package freight, its adaptability to the use of loading and unloading machinery, to the movements of freight from floating to rolling equipment, or vice versa, must be considered.

To handle bulk freight such as coal and iron ore either from boats to docks or from stock piles, docks or cars to floating equipment requires an entirely different class of structure from that designed to handle package freight exclusively. The former may be exposed to the weather, the latter may require protection of warehouses. The character and weight of freight affect the storage and working areas required.

The character of the boats, whether ocean, lake, canal or river-going, whether they are standardized and whether they are equipped with freight-handling machinery, has a very important bearing on the wharf requirements.

Great Lake boats for ore, grain and coal carrying are fairly well standardized. Canal service tends to standardization. Ocean-going vessels are more varied in character.

Labor conditions and character, transient or stable, influence the amount of machinery required for handling freight.

Ownership.

If the dock and wharf property is owned and to be developed by an owner having diversified freight and passenger business to transact, a careful composition of all the factors of possible business development will be necessary.

The relation between the ownership of the docks and transportation equipment calls for attention. If the ownership of both is in the same interests greater permanence to the business justifies broader development of the property.

At the present time the tendency toward government ownership and control may influence the amount of the expenditure to be made. In case of a transfer of ownership a permanent structure would bring a larger proportion of returns than one of temporary character.

Taxation.

On the other hand, other conditions of public sentiment may tend to heavy taxation of the corporation and its property, thus the advantages to be gained by expending money in permanent construction would be offset by the additional taxes on such property.

Insurance.

The fire hazard and insurance rate on property of this kind is very important. If located in the immediate vicinity of structures whose materials increase the fire hazard, fire resistant construction would be advisable. Rates of insurance in different localities should be carefully considered.

Natural Conditions.

The height of the structure is often determined by its location on a shore line subject to rise and fall of the water due to tides, wind action or flood conditions of a river.

The action of salt water upon different structural materials, the climatic and atmospheric conditions, decay and deterioration due to marine growths, violence of wave action, general prevalence of storm conditions, and ice accumulation will all have their influence on the choice of materials. The life of wood commonly used in each locality is a factor in choice of timber or some more permanent form of structure.

The foundation details are variously affected by the character of the soil upon which the structure is to rest. Soft alluvial deposit or sand will often require very long piles, while if rock bottom may be reached without great expense, cribs or piers may be economically constructed. River or stream flow may wash out foundations or fill up adjacent docks. The seasons of the year when wharf may be started might determine the character of construction chosen.

Artificial Conditions.

In most of our harbors conditions imposed by the general layout of the government harbor lines affect the general shape of the work. Where the government harbor lines are laid out far from the natural shore line, construction will develop into long and slender wharves, while if the harbor lines are close in shore, structures will develop into broad and probably filled docks. If the adjacent channels have not been developed to their final form by government decision, it might be unwise to adopt permanent construction. Sometimes riparian rights have not been settled by court decisions and permanence of legal rights should precede permanence of construction.

Business and Economic Conditions.

The business and economic conditions have a most important part. For instance, a lumber wharf built in a country where the timber business will last only ten or fifteen years will suggest a cheap first cost, while a structure to handle package or bulk freight serving ocean liners would naturally suggest structures of permanent design.

The volume of business to be handled at the dock, its rush times at certain seasons of the year, its possibility of increased growth or change of character of shipments may develop a special design.

The availability of previous experience in building wharves in the chosen locality may direct the thought toward the final choice. The first project in a new field often partakes of the nature of an experiment, and to build a permanent structure means waste of capital unless the experiment proves successful.

The volume and gross receipts of the business which may be developed during the early years of operation may determine that the interest and cost of a permanent structure would not be justified.

Sometimes the factor of early completion may, by the increased earnings, justify the more temporary material or may even justify the more expensive material if immediately available.

It may be that materials are abnormally high and based on life period, timber or temporary construction for a short life period to be followed by permanent construction would show greater returns than permanent construction at the start.

The principle of obsolescence places limits on the investment even if no other limit comes in.

Permanent and ornamental structures have a reflex value in advertising and promotion of the business.

Many times judgment on general layouts will be made on the visible and self-evident factors, but the indirect and intangible things may be of greater value. The principle that the breakdown or loss of service of a part of the whole train or sequence of operation may entail loss of many times the cost of permanent construction in the loss of time of the rest of the machine, which may mean delay of all correlated transportation.

The item of maintenance cost is very important. Even at the present prices it may be the deciding factor, but with the upward tendency in the price of materials, repairs may run into larger sums than first contemplated and so balance the increased cost and interest on better structures. Maintenance costs vary through differences in the thoroughness of the system of maintenance, prompt repair oftentimes saving greater losses.

The above discussion or rather suggestion of the many factors of the conception of a wharf and dock layout indicates the broadness of the problem. If it were possible to give each function a factor of evaluation, this article would be of great value, but in the nature of the problem and combination of conditions the factor varies for each project. The real object in displaying the difficulty of the problem is to place before the engineer an outline of complexity of conditions and enable him to understand the structure, the details of which he is to develop.

The foregoing discussion deals with the problem of conception, following with the design and development. No hard and fast lines can be recommended as standard wharf and dock construction.

Design.

The design of wharf structures fundamentally should start from the top and progressively work to the foundation on solid earth at the bottom, but because the elements of the foundation are simpler than the superstructure and the same foundation may serve many kinds of superstructures, it is thought best to give attention here to details of the substructure.

Any substructure may be divided into elements as indicated by the diagram (Plate B), and the notations thereon. The critical region where the greatest variation in design and construction occurs is that next to the dock basin or the part of the wharf which comes closest to the boats, for here we find a variety of forces and requirements.

The vertical loads are to be carried by piling, sheet piling, crib walls and fills. The horizontal pressures where they exist, are to be carried by sheet piling or crib walls. Boat impact and mooring stresses are usually carried by the structure as a whole.

The quality of first importance in a foundation is permanence of form and position during the chosen life period of the wharf. The action of natural forces are destructive rather than helpful in maintaining a structure in place. Of the faults in the foundation uneven settlement is worse than uniform settlement because it sets up destructive stresses in the superstructure. Therefore if settlement seems unavoidable, attention should be given to keeping it as near uniform as possible. This can be attained by using a uniform system of support.

One of the most common causes of failure, and perhaps, the most common defect in dock foundation construction, is the improper spacing of the supporting piling. The tendency is to space piling more or less uniformly throughout the structure with utter disregard of the unequal distribution of load. Often the parts of the dock carrying no load at all are supported by the same distribution of piling as the part of the structure carrying the maximum loads. Piles should be so placed as to receive uniform loading for each pile.

By far the greater number of all docks yet built or being built in this country are designed with wooden piling to carry their loads. In many cases they are being surmounted above water line by concrete piers either with or without timber grillage.

It is becoming more and more the practice at the present time to use treated timber and treated piling in all work subject to destruction by the teredo or other form of marine borers. In the replies to inquiries of the Committee on Docks and Wharves, this recommendation has often been made.

Where piling is driven in very deep water and future plans contemplate permanent filling of the dock, it is often good practice to fill in around the piling to a certain depth with rubble stone, thus stiffening the foundation and causing less damage to buildings and structures due to the shock of berthing boats.

Some structures are surrounded by timber sheet piling well anchored back with steel rods and the wharf then filled to the required height. A few have already used steel sheet piling for this purpose, thereby obtaining a very permanent foundation.

During the past a great many docks have been constructed of timber cribs sunk along the dock line without placing under them piling or other permanent form of support. These structures have been very unsatisfactory. They have caused trouble by settling under load, and by being, easily overturned toward deep water whenever it became necessary to deepen channels. This practice has been almost entirely abandoned, and it is now recognized that filled cribs should never be placed, except upon solid unyielding foundations. Where the improvement will warrant the expenditure, the use of some form of steel sheet piling is very satisfactory, and its use will, doubtless, be increased very greatly in the future.

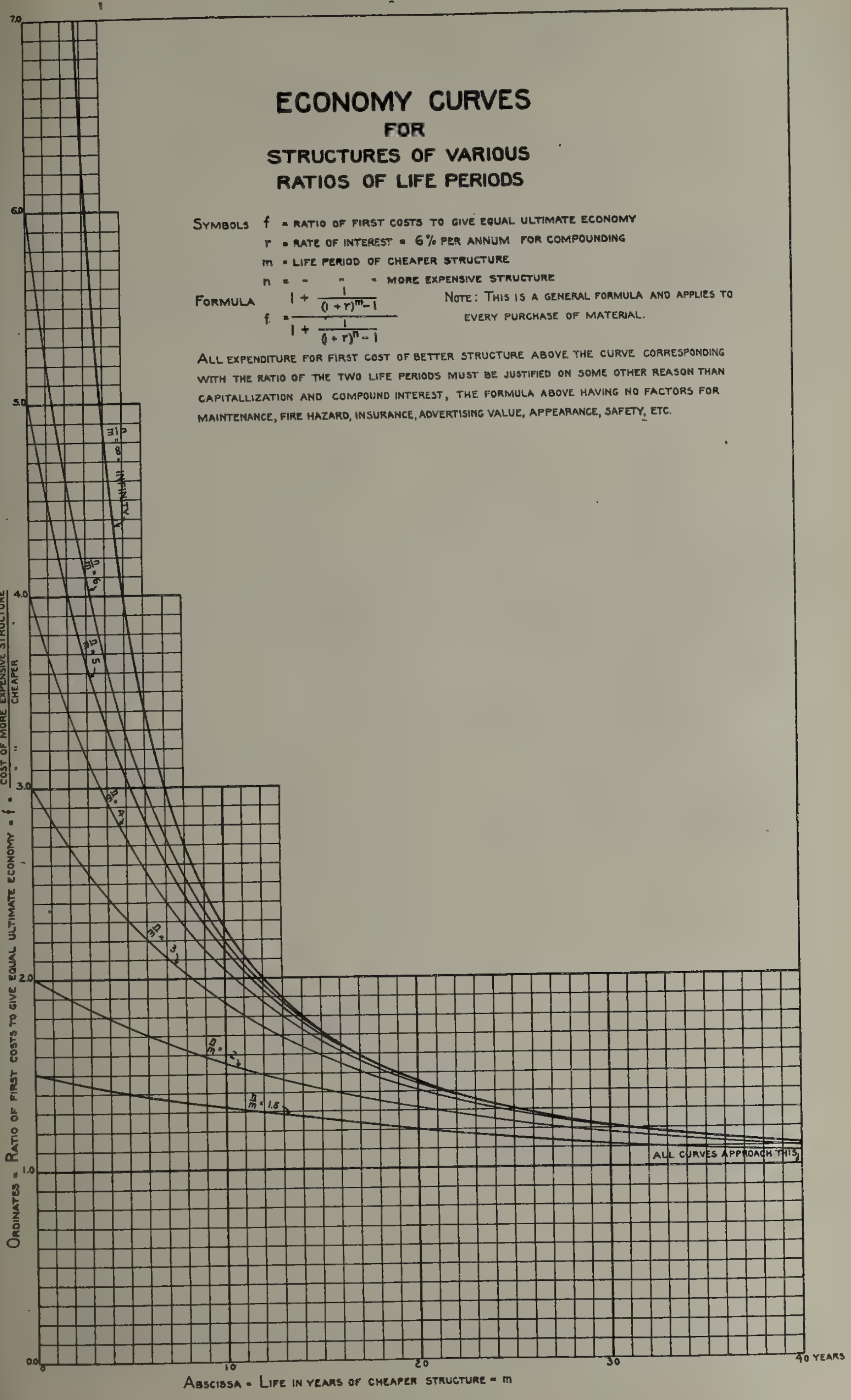
The present depth of channel as well as depth that may be required in the future should be given careful consideration. If the structure is one to be used a long time its future improvement by changing timber foundation to one of more permanent design of concrete and steel must be considered.

Filling behind sheet piling or in cribs should be distributed uniformly and in horizontal layers. Sheet piling walls and cribs should be tight so as to retain all fill permanently. Cribs should rest fairly on suitably prepared bottom.

Ample allowance for strength in the foundation for all loads and forces which may come on the wharf and prevention of overloading later is the best way to minimize settlements.

The following is a list of the more important items to be given consideration in designing wharf foundations:

Timber Piling;
Concrete Piling;
Wood Sheet Piling;
Steel Sheet Piling;
Concrete Sheet Piling;
Rock for Masonry and Fill;



ECONOMY CURVES
FOR
STRUCTURES OF VARIOUS
RATIOS OF LIFE PERIODS

Symbols
f = ratio of first costs to give equal ultimate economy
r = rate of interest = 6% per annum for compounding
m = life period of cheaper structure
n = " " " more expensive structure

Formula
$$f = \frac{1 + \frac{1}{(1+r)^m - 1}}{1 + \frac{1}{(1+r)^n - 1}}$$

Note: This is a general formula and applies to every purchase of material.

All expenditure for first cost of better structure above the curve corresponding with the ratio of the two life periods must be justified on some other reason than capitalization and compound interest, the formula above having no factors for maintenance, fire hazard, insurance, advertising value, appearance, safety, etc.

Plate A

GENERAL DIAGRAM

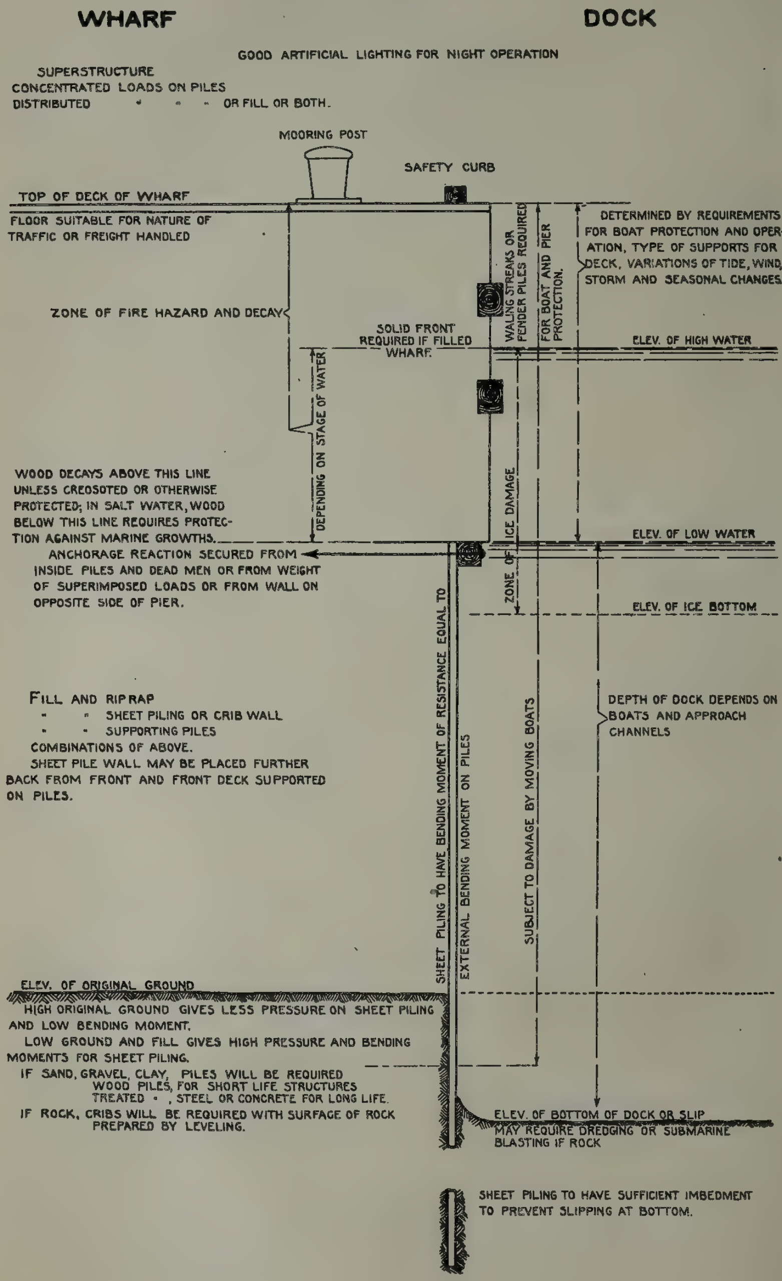

WHARF
DOCK
GOOD ARTIFICIAL LIGHTING FOR NIGHT OPERATION
SUPERSTRUCTURE
CONCENTRATED LOADS ON PILES
DISTRIBUTED " " " OR FILL OR BOTH.
MOORING POST
SAFETY CURB
TOP OF DECK OF WHARF
FLOOR SUITABLE FOR NATURE OF TRAFFIC OR FREIGHT HANDLED
ZONE OF FIRE HAZARD AND DECAY
SOLID FRONT REQUIRED IF FILLED WHARF
WALING STREAKS OR FENDER PILES REQUIRED
FOR BOAT AND PIER PROTECTION.
DETERMINED BY REQUIREMENTS FOR BOAT PROTECTION AND OPERATION, TYPE OF SUPPORTS FOR DECK, VARIATIONS OF TIDE, WIND, STORM AND SEASONAL CHANGES
ELEV. OF HIGH WATER
DEPENDING ON STAGE OF WATER
WOOD DECAYS ABOVE THIS LINE UNLESS CREOSOTED OR OTHERWISE PROTECTED; IN SALT WATER, WOOD BELOW THIS LINE REQUIRES PROTECTION AGAINST MARINE GROWTHS.
ZONE OF ICE DAMAGE
ELEV. OF LOW WATER
ANCHORAGE REACTION SECURED FROM INSIDE PILES AND DEAD MEN OR FROM WEIGHT OF SUPERIMPOSED LOADS OR FROM WALL ON OPPOSITE SIDE OF PIER.
ELEV. OF ICE BOTTOM
SHEET PILING TO HAVE BENDING MOMENT OF RESISTANCE EQUAL TO
EXTERNAL BENDING MOMENT ON PILES
SUBJECT TO DAMAGE BY MOVING BOATS
DEPTH OF DOCK DEPENDS ON BOATS AND APPROACH CHANNELS
FILL AND RIPRAP
" " SHEET PILING OR CRIB WALL
" " SUPPORTING PILES
COMBINATIONS OF ABOVE.
SHEET PILE WALL MAY BE PLACED FURTHER BACK FROM FRONT AND FRONT DECK SUPPORTED ON PILES.
ELEV. OF ORIGINAL GROUND
HIGH ORIGINAL GROUND GIVES LESS PRESSURE ON SHEET PILING AND LOW BENDING MOMENT.
LOW GROUND AND FILL GIVES HIGH PRESSURE AND BENDING MOMENTS FOR SHEET PILING.
IF SAND, GRAVEL, CLAY, PILES WILL BE REQUIRED WOOD PILES, FOR SHORT LIFE STRUCTURES TREATED " , STEEL OR CONCRETE FOR LONG LIFE.
IF ROCK, CRIBS WILL BE REQUIRED WITH SURFACE OF ROCK PREPARED BY LEVELING.
ELEV. OF BOTTOM OF DOCK OR SLIP
MAY REQUIRE DREDGING OR SUBMARINE BLASTING IF ROCK
SHEET PILING TO HAVE SUFFICIENT IMBEDMENT TO PREVENT SLIPPING AT BOTTOM.

PLATE B

Wood Cribs;
Crib Filling;
Sand Filling;
Retaining Walls;
Depth of Channel or Dock adjacent;
Future Depth of Channel or Dock adjacent.

From the above list it will be seen that wharf design of details is an application of specifications and principles which have already been published in previous Proceedings and the Manual of this Association and reference to the indexes thereof will furnish a satisfactory fund of information on nearly all the topics above.

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New South Brooklyn Pier at 35th St., New York. Eng. Rec., December 18, 1915.

Boat Impact and Effect on Wharves.

When a boat strikes a wharf or pier the damage done will depend on the size of the boat, its speed, its material, the mass of the pier, its fender system and material. The designer must consider where he wishes to direct the damage or cost of maintenance. There are two systems directly opposed in principle. The first is to build of materials of such elasticity and make up as will absorb the average service blows with very small damage. Usually this takes the form of elaborate timber framing with fender piles, sometimes backed with coil springs. The exposed points are usually protected with large groups of closely driven piles. However, this protection fails with square blow of a vessel under headway and usually results in expensive damage to the pier. This system has a reverse effect in lessening the skill of the boat captains who do not fear the contact of the wharf with their vessels.

The other system is to build of simple concrete masses or reinforced concrete of such amount and rigidity that boats strike the pier at their own peril. Here a premium is to be put on solidity and mass. Vessels can and do much damage even to these structures, but greater damage is usually sustained by the boat. This tends to increase the skill and diligence of the captains, lessening the frequency of such accidents and usually leaving the structure in a shape to be easily repaired after a destructive blow. Such structures usually only have a rubbing waling strip of oak timber or fender pads of 12 inch by 12 inch timber hung over the side.

Timber piers usually are not adapted to the second system because lacking in mass and rigidity, hence some form of the first system is used.

Where passenger service is rendered by the pier, the second system is not advisable because of the effect on a large crowd of people on the boat of a smashing blow of impact with the pier. Rightly here the practice has developed elaborate systems of cushioning the blow and letting the damage be done to the dock.

Pressures on Sheet Piling.

The general problem of the design of sheet piling has been discussed in the Proceedings of the American Railway Engineering Association before and will be found by reference to the indexes.

The case of submerged wall, with water on both sides, and where filling is put in back may lead to a little confusion. If the water stands at the same level on both sides of the wall the hydrostatic pressures are balanced. The material filled in back of the wall usually weighs more than water even after allowing for the buoyant effect of the water. This gives an added pressure on the side of the wall equal to the horizontal pressure of that material with its slope angle of repose under water and its reduced weight. The effect of the water is to decrease the angle of repose of the material and the effective weight. Decrease of the angle of repose increases the horizontal pressure and the decrease of effective weight lessens the horizontal pressure.

If the material lies fair against the wall so that the hydrostatic pressure has no area to press against, the effective hydrostatic pressure on the inside of the wall will be zero, but in practice a film of water will lie next to the wall except at a few points which transmit the pressure of the filling itself.

Piling, piers and original ground which stands at greater heights than the bottom of the adjacent channel tend to reduce the pressure exerted against the inside of the wall. The amount of reduction is subject for careful judgment in each case. Because of this reduction, it is sometimes possible to leave out intermediate supports on sheet piling, using only secure anchorages at the top and a sufficient length of imbedment at the bottom.

Mooring Posts.

In the early days of wharf building the driving of a strong pile and it left sticking up through the deck three or four feet formed a satisfactory mooring post when the boats were smaller and the attaching lines had a horizontal pull. But with the increase of size and height of vessels which meant high inclination of the rope with a tendency to slip off the old straight side posts, has come cast-iron posts with various shapes to overcome the slipping. All these posts require suitable foundations with hold-down bolts to take care of the lift. With the addition of steam winches on the boats to warp the boats along the piers in loading, it has been found advantageous to have mooring posts at frequent intervals along the front of the pier. It is well also to have a few posts further back from the front to fasten mooring lines at less inclination for such work as pulling the boat closer to the piers.

As a matter of safety, it is necessary that some form of curbing or foothold should be provided along the front of the pier for the men receiving the mooring ropes to prevent their slipping and being pulled into the water.

SUPERSTRUCTURE.

The superstructures of many wharves constructed during the past few years are of a composite character. Timber, concrete and steel are used in various combinations, and there seems to be great diversity of opinion as to the best practice. Of course there are many conditions to be considered in planning a wharf for a particular locality to handle certain classes of traffic, and each is a problem by itself.

Designs submitted to the Sub-Committee on Docks and Wharves show considerable variation in the construction of dock floors. Timber structures are generally decked by cutting off the piling to proper level, capping same with standard sized timbers and placing a plank floor securely spiked to the caps. This form of deck is very satisfactory for wooden structures and, up to the present, on account of the low price of timber, has probably returned more on the investment than would have been produced by any permanent form of construction.

In the past few years some designers have placed concrete decks on timber structures, others have used concrete with asphalt wearing surface. It would seem that either of these methods of construction were hardly satisfactory. Concrete or asphalt decks should be placed on filled or permanent structures so they would not deteriorate rapidly from the action of an unstable foundation.

The superstructure of many wharves is of very simple construction, being principally a more or less extensive roof supported upon posts from the foundation. Of late years many very fine examples of steel and concrete buildings have been erected and the tendency in all our large shipping centers, at the present time, is to erect structures of this character.

The danger of fires and the tremendous loss incident to the destruction of wharves and their contents, as well as the loss that may entail on shipping in the immediate vicinity, has been a very decided factor in producing a permanent form of construction. The constant rise in prices of timber in all forms and the lower prices of steel and concrete is making it more feasible to put up fireproof structures of permanent design.

Plans for proper distribution of electric current for light and power, water pipes for drinking purposes and sanitary uses and fire mains, together with fire-alarm and hose-storage points, are all questions to be carefully considered in designing superstructures.

Economy Curves (Plate "A").

The formula for these curves is given with the curves. By assuming that n and m have a fixed ratio and using various life periods, it is possible to calculate values of f for each ratio of life periods and different lengths of life. By plotting these values of f and joining points calculated for the same ratio of life period, we get curves showing values of f for any life period within the limits of the curves. For convenience those of even life ratio were plotted. For any fractional ratio of life period values of f can be found approximately close by interpellation between the appropriate curves. The curves start at zero life and ratios of cost equal to the ratio of life period and approach the ratio one as the life periods lengthen until at infinity f=one, irrespective of the ratio of cost at the start. The curves are calculated with interest rate at 6 per cent., but the principle would be the same whether we used 3 per cent., 4 per cent., 5 per cent. or 6 per cent. except that the higher the rate the more rapidly do the curves fall to the ratio one.

Example: A tie lasts ten years, how much are we justified in spending for treated tie if it will last twenty years because of treatment? Entering the diagram at 10 at the bottom, carrying our eye up to curve of ratio 2 and reading from the scale of ordinates at the left we find ratio of cost equals 1.55, or if our untreated tie costs 60 cents a treated tie should not cost over 1.55 times 60, or 93 cents. If we spend more than 93 cents we must obtain longer life than double or some other advantage must accrue to the roadbed.

From these curves we can read off by interpellation what life we must get from the more expensive material with a given ratio of first cost.

Example: Wood lasts 10 years and steel may cost twice as much to accomplish the same ends. Entering the diagram at the ratio 2 at the left and noting the intersection with the 10-year life line it is seen that the intersection lies about three-quarters of the distance between the three and four curves or the steel must last 3.75 times as long as the wood or 37.5 years.

By a study of the curves it will be seen that a larger ratio of first cost is justified for short life structures than for long life structures even if the ratios of life periods are the same.

Example: A softwood floor with a life of five years and a hardwood floor of 10-year life we find on the curve 2 that we are justified in spending up to 1.75 times the cost of the softwood floor for the hardwood. With a hardwood floor of 10-year life and a concrete floor of 20-year life we can spend up to only 1.55 times the cost of the hardwood.

From this principle it will be seen that every additional year which we can add to the life of the lesser cost structure lowers the ratio of justified cost of a longer life structure, even though the longer life structure does last the same ratio of life. For example: Treated timber with a life of 25 years and steel of 50 years have a justified cost ratio of only 1.23 and even if we were to get infinite life from the steel only a cost ratio of 1.30 is allowable. This does not prove that steel should not be used, but indicates that where steel is used some other important factor such as maintenance or fire hazard must be the basis for spending a greater amount.

CONDENSED DATA IN REGARD TO DOCKS AND WHARVES FURNISHED BY MEMBERS OF THE ASSOCIATION.

In July, 1914, a circular letter was sent to certain members of the Association who were in a position to furnish data and plans concerning the latest and best practice in the construction of freight-handling wharves. Four questions were asked, as follows:

(a) What were determining factors in the design of this particular dock?
(b) How successful has this design proved?
(c) What improvements would you suggest?
(d) Please give as fully as possible detail unit costs.

Much information and many plans were received showing a great diversity of design adapted to many varying conditions, and the following abstracts and comments are made.

G. W. Harris, Chief Engineer, Atchison, Topeka & Santa Fe Railway, Coast Lines, reports as follows:

We have approximately 4,000 feet frontage of wharf at San Francisco, practically all of which is over a rock sea wall and is driven with creosoted piles, spaced 10 feet each way. The intermediates are 4 inch by 12 inch, and whatever tracks there are, are carried with two pieces of 12 inch by 12 inch under each rail over the 10-foot spans.

At Ferry Point we have a wharf 70 feet wide by 700 feet long extending out into the Bay of San Francisco. In 1913 we extended this wharf and built a new freight apron on the end.

In all of our wharf work we use creosoted piles, treated with sixteen pounds, where same are driven in salt water, as the teredo around San Francisco Bay are very active.

Answering the questions contained in your circular letter, beg to advise as follows:

(a) The Ferry Point extension was designed primarily for the accommodation of our barges handling cars. The wharf on either side of this dock was constructed as a support for the spring line of the slip. The same is true of the wharf around the new slip at Oakland. The wharf at Oakland was driven with this 10-foot spacing of piles, rather than 14 foot, because the original wharf was driven with that spacing with untreated piles and this construction was spaced intermediately with the original with less expense. In new wharf work where tracks are placed on the wharf, the conditions determine whether it is cheaper to use 10-foot spacing or 14-foot.

(b) These designs have proven successful under careful operation of the boats. No timber dock will stand against rough landing of boats, and there is a heavy maintenance cost involved in keeping up these facilities.

(c) The only improvement which I have been looking for is in the method of tieing the brace piles. When a boat lands sufficiently hard against the wharf the first weakness naturally shows in the brace pile, which pulls out of the bolt and sticks up through the wharf. I have thought it would be possible to wedge in these brace piles underneath the cap, but have not used any construction of that kind.

(d) All of these jobs were constructed by contract covering the labor only, the Railway Company furnishing all of the material. Each contract was made up on the basis of unit prices covering each kind of lumber and the different kinds of piles.

At Ferry Point the unit prices were as follows:

Pulling piles	$15.00 each
Taking out old lumber	6.00 per M
Cutting piles off on present wharf to new grade	1.25 each
Drive and fasten standard piles	9.35 each
Drive and fasten brace piles	15.50 each
Drive and fasten Fender and Mooring piles	7.15 each
Drive and fasten Spring piles	11.00 each
Drive and fasten Cluster piles	16.00 each
Drive and fasten Dolphin piles	18.50 each
Placing caps	21.00 per M
Stringers and Compounds	16.00 per M
Planking	11.35 per M
Guard Rail	9.60 per M
Chocks	32.00 per M
Ribbing	31.70 per M
Spring Line Chocks	45.00 per M

Sheathing	18.50 per M
Intermediate Stringers	12.75 per M

Total labor (approximately) .$15,000.00

At Oakland the unit prices were as follows:

Drive and fasten Standard piles	$ 9.00 each
Drive and fasten Brace piles	15.00 each
Drive and fasten Dolphin piles	18.00 each
Drive and fasten Cluster piles	12.00 each
Drive and fasten Spring piles	12.00 each
Placing Caps and sub-caps	21.00 per M
Placing Stringers and Compounds	16.00 per M
Placing Intermediate Stringers	12.75 per M
Placing Planking	11.00 per M
Placing Guard Rail	9.00 per M
Placing Ribbing	34.00 per M
Placing Chocks	40.00 per M
Placing Sheathing	18.00 per M
Taking up old timber	6.00 per M

Total labor (approximately) .$19,000.00

At San Francisco the unit prices were as follows:

Drive and fasten Fender piles	$ 8.00 each
Drive and fasten Standard piles	8.00 each
Drive and fasten Mooring piles	8.00 each
Placing Caps	20.00 per M
Compound Stringers	16.00 per M
Track Stringers	16.00 per M
Intermediate Stringers	15.00 per M
Fillers	10.00 per M
Guard Rail	10.00 per M
Planking	10.00 per M
Removing old lumber	6.00 per M
Placing Chocks	32.00 per M
Breaking off old piles	3.00 each
Pulling piles	12.00 each
Placing sub-caps	25.00 per M

Total labor (approximately) .$17.500.00

Comment.

The plans of these improvements submitted by Mr. Harris show a dock well designed and carefully laid out to serve the purpose intended. His comments on trouble with brace piles show that this question is one very often causing trouble. Many engineers, at the present time, are not using a brace pile in this position, but are using them as ties securely bolted to other piles and operating as sway braces upon a bridge. It is practically impossible to hold a brace pile when constructed as shown in this dock, and keep it from deforming the front and upper deck of the dock. It would seem that planks bolted to the supporting piles and to the caps, acting as sway braces, would be more effective, cause less damage and reduce the cost of maintenance on the dock structure.

As these docks are not designed for carrying heavy concentrated loads covering large areas, the distribution of piling is very satisfactory.

The spacing of piling has been governed by the loads to be taken care of and railroad tracks are properly supported.

George W. Kittredge, Chief Engineer of the New York Central and Hudson River Railroad Company, in answer to our circular letter, reports as follows:

> "Answering your questions in their order:
>
> (a) What were determining factors in the design of this particular pier? Designed for handling outbound business (boats to cars) only. Adequate floor space and numerous gangways in order to make short trucking possible.
>
> (b) How successful has this design proved? The design has proven very successful and entirely satisfactory.
>
> (c) What improvements would you suggest? No suggestions at this time. Since the pier was built we have installed on four of the gangways Otis Elevator Company inclined elevators to assist in handling heavily loaded trucks from barges to floor of pier. This apparatus has been in service only a few months and has been very favorably commented upon by the Operating Department.
>
> (d) Kindly give as fully as possible details of unit cost. The pier was built under a lump sum contract covering the piers and sheds. The total contract cost of the substructure and superstructure, including heating, dry fire protection line, electric wiring and fire alarm system, was in the neighborhood of $3.00 per square foot."

Comment.

The plans for Pier No. 5 at Weehawken, N. J., New York Central Railroad, shows a dock built on pile foundations securely sway-braced with 4 inch by 8 inch plank bolted to each pile, also girt timbers running across the piling underneath the wharf. While some batter piles have been driven in this foundation for stiffening, more dependence is placed on sway bracing, both cross and longitudinal, than upon these batter piles. The wharf has a double layer deck, consisting of a lower 4-inch plank deck covered with 2 inch by 4 inch beech flooring. This gives a smooth, long-wearing surface and should prove very satisfactory. The structure is well designed for the purposes for which it is intended and construction details are good. Its services thus far have been very satisfactory.

J. R. Savage, Chief Engineer of the Long Island Railroad Company, submits plans of the City of New York Department of Docks and Ferries for the Pier and Bulkhead Platforms between James Slip and Oliver Street, Burrough Manhattan. Mr. Savage writes in regard to this dock as follows:

> "We happen to be interested in this particular structure as we rent it from the City of New York and so far as I am aware this represents about the latest practice of the New York Dock Department.
>
> I will reply to your several questions as follows:
>
> (a) This dock was one constantly in use, so that a permanent deck was required.
>
> (b) The design has proven entirely satisfactory.
>
> (c) The only improvement I would suggest would be the use of creosoted timber where exposed to the elements.

(d) I understand the unit cost of timber decks, including rangers, runs about 52 cents per square foot; the reinforced concrete deck costs about 46 cents per square foot and with application of 2½ foot asphalt wearing surface about 55 cents per square foot. The figures for concrete above do not include the cost of timber construction at deck level on the sides of the dock."

Comment.

The plan for the James Slip Dock shows a 9-inch reinforced concrete deck on timber stringers and pile foundation. On top of the 9-inch concrete there is a 2½-inch wearing surface of asphalt. The reinforcing is made up of different sized square bars running from ⅜ inch by ⅜ inch to ⅝ inch by ⅝ inch.

The front of the wharf is fendered with oak piling and timber securely bolted to the main frame work. This design undoubtedly gives a very satisfactory, permanent and fireproof deck. The plan does not show the depth of water and this would have very important bearing on the permanency of the structure.

R. Trimble, Chief Engineer of Maintenance of Way, Pennsylvania Lines West of Pittsburgh, reports on two docks at Sandusky, O., and Cleveland, O., as follows:

"Sandusky, Ohio, new dock for Coal Machine, timber crib construction with concrete top, as shown on plan 15739, attached:

(a) Determining factors in design: Rock foundation. The concrete superstructure was provided in order to make a permanent construction above the water line.

(b) Success of design: It has not been in service long enough to determine the success of the design, but as the same type of dock has been used previously under the same conditions, we do not anticipate any difficulty due to the design.

(c) Suggested improvements: No suggestions.

(d) Detail unit cost per linear foot of dock:

(Average height of crib 18 feet.)

Hemlock lumber	$ 35.00
Framing, placing and sinking	25.00
Iron (tie bolts, drift bolts, etc.)	14.00
Stone (for sinking cribs)	12.00
Leveling foundations	2.00
Concrete top	19.50
Cast-iron Mooring posts	1.50
Total cost per linear foot of dock	$109.00

Cleveland, Ohio, pile dock in connection with new Coal Machine, details as shown on plan No. 15850:

(a) The foundation is sand and clay and timber pile dock was adopted, this type being economical. The two rows of piles with sheeting held by back row is used largely for the reason that where there is any movement of the dock face due to pressure from fill back of same, the front row of piles can be brought to a line without disturbing the anchorage or the rear line of dock piles. In the event of any movement, therefore, the front line of dock can be adjusted if necessary.

(b) While the dock mentioned is now under construction, the same type has been used in this locality for many years and design has been satisfactory.

(c) No suggestions for improvements.

(d) Detail unit costs: Cannot give them."

Comment.

The Sandusky Dock is a good example of filled crib on rock foundation with a monolithic concrete superstructure. The plan is very well worked out, details are good and structure should be satisfactory in every way.

The Cleveland Dock is a good example of a sheet pile front securely anchored back with 1¾-inch diameter rods. It has an unusual feature in that the front fender of the dock is separated from the piling holding the fill. As Mr. Trimble notes, this is for the purpose of lining up the front of dock whenever displaced by uneven settlement of the fill. This front fender portion of the dock is well sway-braced and bolted. Details are good and dock should give entire satisfaction.

F. Merritt, Chief Engineer of the Gulf, Colorado & Santa Fe Railway Company, reports on their dock at Port Bolivar, near Galveston, as follows:

(a) The first factor in determining the design for this dock was first cost, which was controlled principally by the available supply of timber necessary for this construction and foundation cost of other classes of construction. The geological formation consists of alternate layers of water-sand and sea-wilt to an indefinite depth and the cost of a pile foundation for concrete walls with the cost of necessary caisson work would more than equal the entire cost of the present bulkheads and aprons.

(b) Design has proved entirely successful, as evidenced by its continued use at Galveston.

(c) Would suggest that sufficient pile cluster fenders be placed under the outer edge of apron to land boats against instead of landing directly against the apron. This will reduce cost of repairs to apron one-half.

(d)

Total cost of bulkhead per linear foot	$33.27
Total cost of apron 30 ft. wide per sq. ft.	0.7343
Cost per linear foot marine treated piles	0.385
Cost per linear foot untreated piles	0.085
Cost per M. feet B. M. marine treated timbers	47.80
Cost per M. feet B. M. full-cell treated timbers	31.00
Cost per M. feet B. M. untreated timbers	21.80
Cost per linear foot driving marine treated piles	0.17
Cost per linear foot driving untreated piles	0.15
Cost per M. feet B. M. placing marine treated timbers	16.00
Cost per M. feet B. M. placing other timbers	15.00

Average cost of freight on piles about $0.05 per linear foot, and on timbers about $5.00 per M. B. M.

Comment.

The dock reported upon by Mr. Merritt is a timber platform supported on pile foundations. Back of dock proper sheet piling has been driven and tied back by ½-inch iron rods to anchor piles and the dock filled. This dock should be very satisfactory for the purpose designed.

G. C. Cleveland, Chief Engineer, New York Central Railroad, West of Buffalo, submits plan of rock-filled crib dock at Ashtabula, O. The timber cribs are 21 feet wide, 19 feet high and filled with one-man rubble limestone. Cribs are of the usual form of construction, solid face wall with open bulkheads spaced 8 feet apart. Vertical posts at each corner of bulkheads are securely bolted to face and cross timbers. He gives no information in regard to costs.

F. B. Freeman, Chief Engineer of the Boston & Albany Railroad, reports as follows in regard to their docks at Boston:

"The Docks and Wharves of the Boston & Albany Railroad are not very extensive. They were rebuilt after the big fire of 1908 with considerable speed, so that there was not time available to give the designing of them, particularly the dock work, as much consideration as probably they deserved.

In answer to your questions, however:

(a) As to the determining factors in the designing of our docks. They are as follows:

To be available for the largest class of trans-Atlantic steamers, of the type known as Combination, that is—handling a full list of passengers and a heavy tonnage of freight. It was necessary to take care of the trans-shipment of miscellaneous freight, at the same time handle grain. It was also desirable that the arrangement should be such that export freight could be handled into the ship at the same time that import freight was being handled out of the ship, as the period of stay in the dock was to be defined and limited, due to regular dates being arranged for the sailings.

The feature of the grain trade was taken care of by the placing of the Grain Elevator inshore, back from the docks, and conveying the grain through grain galleries to spouting towers into the ship, the towers being arranged considerably higher than the pier sheds, so that they do not in any way interfere with the handling of miscellaneous freight from the sheds.

The passenger business is taken care of by the construction of a second story on the shed, where all passengers, immigrants and baggage can be handled.

The feature of handling export and import freight at the same time was taken care of by making the piers considerably wider than is the practice, for instance, in the Port of New York.

(b) How successful has this design proved? I should say that the arrangement of the East Boston piers has been very successful.

(c) What improvements would you suggest? The improvements that we could suggest are so many that it would take considerable time to mention them all, but I should say that the first suggestion we would make in the construction of piers is the elimination of timber, as far as possible, both in sub-structure and super-structure. In the sub-structure, in many locations, it might not be possible to accomplish this, but we are of the opinion that for the super-structure, the use of timber should be barred altogether.

Another suggestion would be, that where possible, the outer walls, instead of being constructed as they are in almost all docks, at the present time, of some light galvanized iron or other form of sheathing, should be constructed of some solid material, possibly, for the sake of lightness, a tough vitrified hollow tile material.

Where possible, I would suggest also, that the floor of the pier be of some hard material, to reduce the very heavy cost of maintenance of wooden floors and also for the reduction of fire risk.

Where fire protection is installed, instead of distributing the monitors and hose nozzles at different points on the floor of the pier, I believe that the cost of a narrow gallery around the outside of the building, the bottom of the gallery to be practically on a level with the top of the doors, from which all of the fire protection apparatus could be operated, would be a very big improvement, both in the cost of maintenance and in its availability, as under the present general arrangements in freight piers the positions of the fire fighting appliances are generally such that they are subject to constant breakage or damage during the handling of freight and there is the probability of their being blocked up from access by the piling of freight around them.

We would suggest that in all cases provision be made for electric winches to take care of the handling of miscellaneous freight from the docks to the ships and vice versa.

We would suggest that the matter of the arrangement of water pipes calls for the most careful consideration, so as to get it economically located and in such a way that it can be fully protected by some heating arrangement. This undoubtedly could best be accomplished by carrying the main supply down through the center of the shed on a gallery arrangement.

(d) In regard to detail unit costs.

I regret to say that up to date we have never had an opportunity to work out the unit costs on this work, but I would say that the total cost of each pier was approximately $750,000.00. This includes substructure, pier and pier shed on it, and fire protection system, which is exceedingly elaborate on these piers, but exclusive of the grain galleries.

G. J. Ray, Chief Engineer of the Delaware, Lackawanna & Western Railroad Company, reports as follows:

"Under separate cover I am sending you one complete set of blueprints and specifications of our pier No. 8, Hoboken Terminal, also a cross-section of our pier No. 9, showing how this construction is adapted to the use of two-story pier shed building.

(a) We endeavored to design a structure which would be fireproof with a minimum of maintenance.

(b) Piers have been in use about eight years, with practically no maintenance expenses; in case of fire it would be out of the question to have any serious damage.

(c) We have designed four other piers of this type with practically no changes in design.

(d) Cost of open pier $2.25 per square foot; two-story pier $4.25 per square foot."

Comment.

The Hoboken Terminal Pier No. 9 is a two-story steel and reinforced concrete structure supported on pile foundations stiffened with rip-rap and rubble filling. It is a good example of a structure designed for economical operation, two stories in height. The structure is simple, details good and should be a very satisfactory plan for this method of operation.

J. L. Pickles, Chief Engineer, Duluth, Winnipeg & Pacific Railway, submits plan of dock designed exclusively for handling lumber from railroad cars to boats. This is a structure quite common at Lake Superior ports. The design submitted by Mr. Pickles is one of the latest and best, the details are good and costs are low. Mr. Pickles gives the following report:

(a) What were determining factors in the design of this particular dock? Position and shape of real estate, likelihood of future extensions and the construction of other docks and buildings.

(b) How successful has this design proved? So far the dock has proved wholly successful.

(c) What improvements would you suggest? I would suggest that all bolts exposed on the outside of the dock be countersunk so as to prevent scarring boats moored alongside. I would also suggest toilet facilities be provided and an adequate office building for employes.

(d) Kindly give, as fully as possible, detail unit prices:

Engineering charges	$ 1,409.34
Freight charges on piling, ties and planking	5,089.26
Piling—lin. ft.—103,185	17,539.45
Timber—F. B. M.—818,230	22,702.29
Machine bolts, drift bolts, etc	1,479.96
Iron cleats—25 at $8.75	218.75
Contract price driving piles 92,791 lin. ft. left in work at 5¾ cents	5,335.48
Contract price framing deck and bracing 781,699 ft. B. M. left in work at $6.90 per M.	5,393.72
Excavating for mud sills on bank	119.41
Crib at end of Dock:	
Iron rods for tieing crib	19.10
Labor applying rods	44.10
Stone for filling crib—64 cords at $7.00	448.00
Dredging: 177,427.4 cubic yards at 11 cents	19,517.01
Track: 60-lb. rails and fastenings, 2nd hand	1,688.90
Labor	320.43
Saunders Car Stoppers, 2 at $45.00 each	90.00
Freight on Car Stoppers	7.28
	$81,422.48

W. L. Rohbock, Chief Engineer of the Wheeling & Lake Erie Railroad Company, submits plans of an extension to one of their ore and coal handling docks. It is an excellent example of a structure designed to carry heavy loads piled over the surface of the dock. The front is timber construction, sheet piling in the rear of the dock proper and the main body of the dock filled. The timber front of the dock is very efficiently anchored back with steel rods, which was made necessary on account of the heavy loads to be handled.

William Michel, Chief Engineer of the Hocking Valley Railway, submits plans of a dock at Toledo, O. This structure is another good one typical of the ore and coal-handling docks on the Great Lakes. It is an excellent example of crib-filled structures and of concrete pier supported directly on piling. On account of the heavy distributed loads to be carried and the heavy machinery foundations it requires a very solid substructure. It is also thoroughly tied back with anchor rods.

Mr. Michel submitted the following report as to questions:

"(a) Limited dock frontage was responsible for the adoption of the special slip dock arrangement. The pile and concrete dock construction was adopted for the pier because the two walls could be securely tied together and prevent spreading of the main walls and keep them in line. Where this could not be done the crib and concrete dock construction was used and the walls securely anchored to piling driven into the fill behind the dock wall.

(b) We had some difficulty in landing the cribs and keeping them in line while they were being pumped full of sand. The design thus far has proven successful.

(c) Have none to suggest, as we are just putting the dock into operation, and so far nothing of a serious nature has developed.

(d) 12" x 12" timber grillage placed	$43.00	per M. B. M.
2" plank, hardwood	38.00	" "
2" plank, hemlock	35.00	" "
Timber piling driven	.28	per lin. ft.
Steel piling driven	.02	per lb.
Concrete placed	6.80	per cu. yd.
Steel "I" beams placed	.02	per lb.
Steel reinforced rods placed	.02½	" "
Wrought iron rods placed	.05	" "
Dredging and waste	.23	per cu. yd.
Dredging and backfill	.27	" " "

The above prices do not include Company freight or supervision."

W. H. Courtenay, Chief Engineer of the Louisville & Nashville Railroad Company, submits plan of their Warehouse and Wharf at Pensacola, Fla. This is a two-story structure, entirely of wood, and is designed for handling freight unloading on both floors at the same time.

Mr. Courtenay reports as follows:

"In response to your letter of July 20th, subject 'Inquiry as to Docks and Wharves,' I am sending to you, under separate cover, blueprint G-510 showing a cross-section and part longitudinal section of our Commendencia Street Wharf at Pensacola, Fla., which is the latest dock of importance built by this Company.

This dock is 1200 feet in length, and has slips on each side of it, with 28 ft. depth of water. The central portion, or the portion between the tracks is enclosed. The sides of the outer portion, or between the walls of the warehouse proper and water on each side, are not enclosed.

You will observe that tracks reach each floor.

Freight is discharged from vessels to both floors of this structure concurrently. Likewise freight is unloaded from the warehouse to vessels from both floors concurrently.

It was considered that this type of dock would suit the necessities of the Railroad Company at Pensacola better than any other.

The design has, I think, proven to be eminently successful.

I have no improvements to suggest at this time.

The piles supporting this structure are longleaf yellow pine, creosoted, the remainder of the structure is built of green timber.

The floors have carried loads weighing as much as 1200 lbs. per square foot, although this structure was not designed for such excessive loads."

C. F. Loweth, Chief Engineer of the Chicago, Milwaukee & St. Paul Railway, submits plan of their dock in Chicago River. This is a very simple structure composed of a front row of piling with sheet piling anchored back to anchor timbers and piles with 1¼-inch rods, the dock is then filled.

Mr. Loweth reports as follows:

"Answering your inquiries, would say that one of the factors aimed at in the design of this and other docks is to get the anchor rods low enough so they will be efficient after the piles have begun decaying above the water level, and an endeavor has been made to make the anchorage sufficient to withstand heavy loading on the docks, such as large bodies of coal, etc.

The plan shown on the attached print, which in a general way represents our standard practice, has quite successfully met our requirements, but for exceptional locations we might make material changes of design.

These docks in Chicago and Milwaukee cost from $18.00 to $25.00 per linear foot, depending upon local conditions."

W. L. Darling, former Chief Engineer of the Northern Pacific Railway, submits plan of their Yesler Wharf in the City of Seattle. This structure is entirely of timber supported on pile foundations. It is a good example of the Pacific Coast Harbor construction.

Mr. Darling reports as follows:

"The 1909 extensions cover an area of 80,600 square feet of dock and 62,000 square feet of warehouse.

The remodeling of pier one in 1912 covered the raising of the roof for a second story on the old warehouse, providing balconies and offices on each side of the house with waiting rooms, ticket office, room for custom inspectors, detention room, etc., and for additional piling and the necessary strengthening of the dock otherwise, to take care of the increased load.

The construction is based upon a loading of 420 lbs. per square foot, including weight of floor, for the first floor, and 150 lbs., including weight of floor for the waiting room.

The number of piles were determined by the load, and the lengths, which vary from 50 to 90 feet.

The plans you will find illustrate the situation quite fully.

The design has proved very satisfactory for the purposes intended.

The cost of the extension and remodeling aggregates about $300,000.00."

The plans and data quoted above are only a part of the many furnished the Committee from all parts of the United States, and show a great variety of docks and wharves suited to handling nearly all classes of freight and passenger traffic. The materials of construction range from all timber to all concrete and steel with many combinations of both.

It is impossible to discuss in detail the many different types of structures used in this country for docks and wharves, and this report is submitted for the information of the members of the American Railway Engineering Association.

American Railway Engineering Association

VOL. 19, NO. 197 . . . . JULY, 1917

ADDITIONS TO MEMBERSHIP.

1984. Whyman, R. G.,
Division Engineer, Atchison, Topeka & Santa Fe Railway, Amarillo, Texas.

1985. Ryder, E. M. T.,
Engineer Maintenance of Way, Third Avenue Railway Company, New York, N. Y.

1986. Cunningham, C. C.,
Division Engineer, Chicago, Rock Island & Pacific Railway, Herington, Kansas.

1987. Wilson, H. P.
Assistant Valuation Engineer, Texas & Pacific Railway, Dallas, Texas.

1988. Crawford, C. H.,
Assistant Engineer, Nashville, Chattanooga & St. Louis Railway, Nashville, Tenn.

1989. Cranfield, R. E.,
Assistant General Manager and Chief Engineer, Tampico Valley Railway, Tampico, Mexico.

1990. Kinzie, S. A.,
Division Engineer, New York, New Haven & Hartford Railroad, Taunton, Mass.

1991. Podmore, John M.,
Division Engineer, New York Central Railroad, Toledo, Ohio.

1993. Gaby, F. A.,
Chief Engineer, Hydro-Electric Power Commission of Ontario, Chief Engineer, London & Port Stanley Railway, Toronto, Canada.

1994. Bieth, R. J.,
Division Engineer, New York, New Haven & Hartford Railroad, New London, Conn.

1995. Edwards, J. P.,
Division Engineer, Southern Pacific Company, Bakersfield, Cal.

1996. Martin, E. L.,
Engineer Maintenance of Way, Missouri, Kansas & Texas Railway, Dallas, Texas.

1997. Yamada, Takaji,
Civil Engineer, Imperial Government Railways, Tokyo, Japan.

1998. Desmond, J. J.,
Roadmaster, Illinois Central Railroad, Water Valley, Miss.

1999. Holmes, H. B.,
Chief Engineer, Kansas City, Mexico & Orient Railroad, Kansas City, Mo.

2000. Waring, F. M.,
Acting Engineer of Tests, Pennsylvania Railroad, Altoona, Pa.

2001. Metcalf, J. M.,
Assistant Engineer in Charge of Relocation Surveys, Missouri, Kansas & Texas Railway, Parsons, Kansas.

2002. Sammy, George,
Bridge Engineer, Western Maryland Railway, Baltimore, Md.

2003. Johnson, E. A.,
Superintendent Bridges and Buildings, Maine Central Railroad, Bangor, Maine.

CHANGES OF TITLE AND ADDRESS.

J. C. Nagle, Dean of Engineering and Professor of Civil Engineering, Agricultural and Mechanical College of Texas, College Station, Texas.

G. T. Kuntz, Assistant Engineer, Union Pacific Railroad, Ellis, Kansas.

H. A. Palmer, Assistant Land Commissioner, Grand Trunk Railway, Montreal, Canada.

C. S. Flandreaux, Track Supervisor, New York, New Haven & Hartford Railroad, Providence, R. I.

L. F. Goodale, 5188-A, Page Boulevard, St. Louis, Mo.

B. C. Martin, District Engineer, New York Central Railroad, Castleton, N. Y.

H. Bortin, Consulting Valuation Engineer, 149 Broadway, New York City, and 408 Olive Street, St. Louis, Mo.

H. T. Sympson, Assistant Division Engineer, Pennsylvania Lines West, Cleveland, Ohio.

J. S. Browne, Assistant to Engineer Maintenance of Way, New York, New Haven & Hartford Railroad, New Haven, Conn.

W. W. Colpitts, care Coverdale & Colpitts, 66 Broadway, New York City.

C. A. Daley, Assistant Division Engineer, Erie Railroad, Elmira, N. Y.

F. T. Howes, Resident Engineer, Northern Pacific Railway, Brainerd, Minn.

John S. Goodell, Assistant Engineer, Atchison, Topeka & Santa Fe Railway, Holyrood, Kansas.

W. P. Ball, Assistant Division Engineer, Cincinnati, Hamilton & Dayton Railway, Dayton, Ohio.

James Richardson, Bridge Designer, Lehigh Valley Railroad, South Bethlehem, Pa.

T. E. White, Assistant Chief Engineer, Louisiana & Arkansas Railway, Stamps, Ark.

P. S. Lewis, Passenger Trainmaster, Philadelphia & Reading Railway, Reading, Pa.

D. W. Cronin, Division Engineer, Baltimore & Ohio Railroad, New Castle, Pa.

T. C. Crea, General Superintendent, John W. Cowper Company, Buffalo, N. Y.

Geo. W. Godlove, Assistant Engineer, Atchison, Topeka & Santa Fe Railway, Orrick, Mo.

A. R. Bailey, 2627 Grand Central Terminal, New York City.

L. A. Downs, General Superintendent, Illinois Central Railroad, Chicago, Ill.

Howard Elliott, Chairman, Executive Committee, Northern Pacific Railway, New York City.

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E. H. Barnhart, Division Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

A. E. Clift, General Manager, Illinois Central Railroad, Chicago.

W. A. Cowan, General Superintendent, Canadian Government Railways, Cochrane, Ont., Canada.

C. R. Morrill, Assistant General Manager, Southern Pacific Company, Houston, Texas.

J. F. Deimling, Acting Chief Engineer, Michigan Central Railroad, Detroit, Mich.

C. H. Byers, District Engineer, Interstate Commerce Commission, San Francisco, Cal.

F. P. Gutelius, Vice-President and General Manager, Delaware & Hudson Co., Albany, N. Y.

PERSONAL NOTICES.

W. A. COWAN has been made General Superintendent of the Canadian Government Railways, with headquarters at Cochrane, Ont. The principal part of Mr. Cowan's railway experience has been with the Canadian Pacific Railway, whose service he entered in 1905. He was successively Assistant Engineer of the Toronto Terminals, Resident Engineer, Assistant Engineer of Maintenance and Superintendent. In 1914 he entered the service of the Canadian Government Railways as Resident Engineer and was later promoted to Division Engineer.

L. A. DOWNS has been transferred to Chicago as General Superintendent of the Northern Lines of the Illinois Central Railroad, succeeding A. E. Clift, promoted to General Manager. Mr. Downs is a graduate of Purdue University and entered railway service on the Chicago & Eastern Illinois Railroad in 1893 on location work. In 1894 and 1895 he was with the Vandalia Railroad as Draftsman and Assistant Engineer, and in the latter year entered the service of the Illinois Central Railroad, with which company he has been connected up to the present time, being successively Assistant Engineer, Chief Engineer of proposed Saltville & Mendota Railroad (a subsidiary of the Illinois Central Railroad), Roadmaster, Superintendent and General Superintendent.

Mr. Downs is a Charter Member of the American Railway Engineering Association and has taken an active part in its work. He was

Chairman of the Committee on Ties for several years and at the last annual convention was elected a Director.

Thos. C. Crea, heretofore Assistant Engineer of the Bessemer & Lake Erie Railroad, has been appointed General Superintendent of the John W. Cowper Company, with headquarters at Buffalo, N. Y. Mr. Crea entered the service of the Bessemer & Lake Erie Railroad on June 1, 1905, and was subsequently Draftsman, Assistant Transitman, Transitman in Charge of Field Party, Track Supervisor, Supervisor of Structures and on June 1, 1915, was appointed Assistant Engineer.

A. E. Clift has been appointed General Manager of the Illinois Central Railroad, with headquarters at Chicago. Mr. Clift entered railway service in the Transportation Department of the Big Four Railway, subsequently taking service with the Illinois Central Railroad, with which company he has been identified up to the present time, being successively Freight Brakeman, Yardmaster, Freight Conductor, Passenger Conductor, Trainmaster, Superintendent and General Superintendent.

Mr. Clift has for years been an active member of the Committee on Yards and Terminals and has given especial attention to freight handling by mechanical means and yards and terminal operation generally.

C. R. Morrill has been appointed Assistant General Manager of the Southern Pacific Company, with headquarters at Houston, Texas, succeeding E. B. Cushing upon the latter's appointment as Major in the Officer Engineers Reserve Corps. Mr. Morrill is a graduate of the Agricultural and Mechanical College of Texas and entered the service of the Southern Pacific Company, Atlantic System, in 1893. He served as rodman, transitman and draftsman until 1897, when he was appointed roadmaster of Morgan's Louisiana and Texas Railway and Steamship Company, a subsidiary of the Southern Pacific Lines. In 1900 he was promoted to Resident Engineer, Division Engineer and Assistant Superintendent of the Galveston, Harrisburg and San Antonio Railway. From June, 1915, up to his recent appointment he was Superintendent of the Houston & Texas Central Railroad Company, also a subsidiary of the Southern Pacific Lines.

F. P. Gutelius, who has been appointed Vice-President of the Delaware & Hudson Company, with headquarters at Albany, N. Y., entered railway service in the Engineering Department of the Pennsylvania Lines. After a few years of private practice in the Northwest he was made General Superintendent of the Columbia and Western Railway in charge of construction and operation. He then entered the service of the Canadian Pacific Railway as Superintendent of the Rossland Branch. He subsequently was appointed Assistant Chief Engineer with headquarters at Montreal and was later transferred to the Transportation Department as General Superintendent. In 1913 he was appointed General Manager of the Canadian Government Railways, with headquarters at Moncton, N. B., which position he held until his recent appointment as Vice-President of the Delaware & Hudson Company.

BULLETIN

OF THE

American Railway Engineering Association

Vol. 19, No. 198 . . . . AUGUST, 1917

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By Sanford M. Zeller,
Research Fellow, Henry Shaw School of Botany,
Washington University

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American Railway Engineering Association

VOL. 19, No. 198 . . . . AUGUST, 1917

FOREWORD.

The two chief requisites for the proper use of timber for construction purposes are strength and decay resistance. In the past, whenever a strong piece of Southern yellow pine was desired, specifications called for strictly longleaf yellow pine. Great confusion resulted, however, due to the fact that there was no method by which an Engineer could determine whether he actually received longleaf yellow pine or not. Realizing this difficulty, the American Society for Testing Materials, in cooperation with the United States Forest Service, after a good many years of investigation, finally formulated a rule (which was subsequently adopted by the American Railway Engineering Association) which ignores the botanical classification of Southern pines and establishes the density as a basis for strength classification of structural yellow pine timbers. This density rule has now been in general use for several years and may be regarded as a safe guide for separating the stronger from the weaker pieces.

Very little has been known as to the relation between relative decay resistance of the different species or qualities of Southern pines. Recognizing the importance of this subject, the Southern Pine Association established a technical fellowship at the Missouri Botanical Garden for the purpose of conducting a careful investigation concerning the relation of the physical and chemical factors influencing decay resistance. This investigation was conducted under the auspices of the Missouri Botanical Garden by Mr. Sanford M. Zeller, Research Fellow in the Henry Shaw School of Botany of the Washington University. Mr. Zeller issued a preliminary report on the factors influencing the growth of the worst wood-destroying fungus, which was published in the Annals of the Missouri Botanical Garden, Volume III, pages 439 to 515, 1916. The second paper by Mr. Zeller, reprinted herewith, deals with the more practical phases of decay resistance in various kinds of Southern pines, and represents the first distinct contribution toward this important subject.

Particular attention is called to the conclusions, indicating that in the selection of high-grade bridge materials of Southern pine, the density factor will not only be a safe guide to strength but also to decay resistance, provided sufficient restrictions as to sapwood are incorporated. The present standard rules of the A. R. E. A. as to sapwood and heartwood for high-grade bridge materials amply fulfill this requirement. It is encouraging to note that the density rule plus the sap restriction may be applied with safety to any piece of Southern pine irrespective of botanical species.

Hermann von Schrenk.

STUDIES IN THE PHYSIOLOGY OF THE FUNGI.

III. PHYSICAL PROPERTIES OF WOOD IN RELATION TO DECAY INDUCED BY LENZITES SAEPIARIA FRIES.

Sanford M. Zeller,
Research Fellow in the Henry Shaw School of Botany of
Washington University.

Introduction.

Much interest has been manifested among the lumbermen and those associated in allied industries concerning specifications for structural timber. The classification of structural timber is based on strength and durability. Members of the Forest Service at the Forest Products Laboratory, Madison, Wisconsin, have shown that the true criterion of the strength of wood is its density (specific gravity), and that the percentage of summer wood indicates its density (Betts, '15).* †But the physical properties of wood, which influence its durability, hitherto have presented an open question, and it is the purpose of this paper to report the investigations on this subject carried out by the author at the Graduate Laboratories of the Missouri Botanical Garden.

The experiments were conducted with three species of yellow pine, *Pinus palustris,* P. *echinata,* and P. *Taëda.* Special attention was given to the physical properties of each sample of wood used, data being secured on (1) resin content, (2) specific gravity, (3) percentage of summer wood (the dark portion of the annual growth ring) or proportion of summer wood to spring wood in the growth rings, (4) the width of the growth rings or number of rings per inch measured on a radius of the stem, (5) sap- and heartwood, and (6) the distance of the sample from the pith.

Susceptibility to decay and comparative resistance to fungous attack vary with the different species of wood, and it was believed that in any one species various qualities of the wood may influence its durability. Therefore, in the series of experiments reported below the three species of yellow pine were used, and a comparison of their relative resistance will be discussed. However, before describing the experiments and their results it will be necessary to consider the results of previous workers who have contributed to our knowledge of the influence of the physical properties of wood upon its durability.

Historical Review.

Resin occurs widely distributed in the plant kingdom as a solid, semi-liquid, or dissolved in a resin solvent. It is most abundant in coniferous wood, where it exists in the sapwood dissolved in terpenes or turpentine oils, and in the heartwood as an amorphous solid or semi-liquid mass, according to the degree of seasoning and age of the heartwood. Various types and compositions of resin are found in many other groups of plants. Harz ('68) showed by analyses that it is to be found in the mycelium and fruiting bodies of *Polyporus officinalis* Fries, and more recently Malencovie ('07) has reported it in the mycelium and sporophores of *Lenzites saepiaria*. Resin has been generally considered a hindrance to the attack of wood-destroying fungi.

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*In a later paper the author will discuss the literature on the grading rules of structural timbers as they relate to strength, as well as the results of an experimental study of the relation between strength and durability of yellow pine timber.

†References are to Bibliography, pp. 59, 60.

In discussing the inroads of the mycelium of *Trametes Pini* Fr., Hartig ('78) says that the terpenes and oils of turpentines are driven out of the wood in advance of the fungus, and the resin which is soluble in the terpenes is carried forward until it becomes so concentrated as to form a barrier or resistant wall, as it were. This is especially true in the sapwood where resin exists in certain species of wood diluted in the terpenes. In the heartwood where the resin is in a more or less solid condition it is difficult to conceive that it may be driven out by the entrance of the mycelium, yet the pressure of the mycelium might result in an increased tension in the tissues, as may be the case in those forms of decay described by von Schrenk ('01, p. 204). Thus, coniferous trees should be pruned when young, at least before any heartwood is formed, so that the resin will exude and cover the wound, since, as was demonstrated in a previous paper (Zeller, '16), fungi will not germinate nor grow on pure solid resin as it exudes from the wounded bark or sapwood.

Hartig's observations, referred to above, were made in the field. He states that in the summer of 1877 damage done by wind gave opportunity to study the aseptic influence of resin on wounds. In all cases of fracture there was exudation from the sapwood, but not from the heartwood. He further noticed that where resin in the solid state is infiltrated in the cell walls and also fills the cell lumen the penetration of the fungous mycelium is mechanically hindered.

Temme ('85) believed that certain kinds of wood are rendered more durable by a gum which is formed in wood exposed to air. This is especially true where active sapwood is exposed as the result of a lesion. Bordering the active wood thus aërated a layer of "Schutzholz" is formed because of the infiltration of this gum, which, he believed, made the wood resistant to fungous attack.

Dudley ('87) observed that longleaf pine (*Pinus palustris*) does not seem to be exceptionally durable when placed in conditions favorable to the growth of fungi, as in roadbeds as railroad ties. He states that "ordinary specimens of this pine contain from 18 to 20 per cent. of resinous matter, which is supposed to add much to the durability of the wood. But this does not seem to be the case when the wood is put in the ground or in the roadbed as ties."

To Mayr ('94) we are indebted, probably more than to any other worker, for our present knowledge of the influence of resin on the durability of coniferous woods. He has made an extensive study of the distribution of resin in the woody tissues and also of the physiological importance of the resin to the tree, besides drawing quite definite conclusions as to its influence on fungous growth.

Mayr distinguishes between the liquid resin, as it is found in the sapwood of conifers, and solid resin, such as fossil amber. Fungi such as *Nectria* and *Pestalozzia* thrive on the soft resin, while the hard resin is very durable. Thus, the greater the amount of hard resin wood contains, the more durable will it be. He suggests that the influence of resin should not be overestimated, however, since other factors, such as density or specific gravity, dark color due to the impregnation with "Dauerstoff," climatic conditions under which the trees were grown, and the duration of seasoning, are of much greater importance in decay resistance. On the other hand, where different species of coniferous wood have the same specific gravity, Mayr ascribes the differences in durability to variations in resin content. Pieces of spruce, larch and Douglas fir, for instance, often show the same specific gravity, but the spruce and larch are generally more durable than the Douglas fir, since the latter is considerably inferior in resin content.

Mayr further says that for the judging of the durability of all species of wood, the "Dauerstoff," a substance or substances which cause the dark color of heartwood, must be taken into consideration; that is, that a species of wood possessing dark heartwood surpasses in durability that with light-colored heart, providing the resin content and specific weights are the same.

The climatic conditions under which the trees are grown will influence the durability of the wood. Mayr suggests the pine as an example of this fact. For instance, the timber grown in relatively warm climates on sandy soils possesses a dark, broad heart, while that produced on gravelly soils in cooler climates has narrow, light-colored heartwood, and under warmer conditions the wood is specifically heavier and possesses a greater resin content than in cooler regions.

It is also suggested in Mayr's conclusions that the seasoning of the wood influences the durability because of its effect on the resin content. If seasoning is rapid the resins may be carried out of the wood by the evaporation of the turpentine and water, but, if slow, the hard resins are laid down within the wood, thus increasing durability.

We notice here that Mayr seems to lay as much stress upon specific gravity as a factor in the resistance of wood to fungous decay as he does on the resin content. Practically the same idea is conveyed by Falck ('09), who says that all three species of *Lenzites* (*L. saepiaria, L. abietina,* and *L. thermophila*) will attack pine sapwood more readily than heartwood, and coarse-grained or non-resinous sapwood more readily than dense or resinous material. Pine heartwood is attacked with difficulty, even by *Merulius lacrymans*, and hard, resinous knots, etc., are always immune.

Speaking of the decay of wood produced by *Lenzites saepiaria,* Spaulding ('11) suggests that resin is a factor in the resistance of Southern pine. He states that "Whether it is able to rot the resinous heartwood of the Southern pines seems questionable. The writer has seen no instance where this has taken place, except in the outer layers of heartwood which were not so completely filled with resin as the inner ones."

Hoxie strongly advocates resin as a criterion of the durability of pine wood. However, he has advisedly included in his specifications (Hoxie, '15) density (specific gravity of about .48), percentage of summer wood (33.3 per cent.), and growth rings per inch as factors of importance. In 1914 he performed a very simple experiment from which he concluded that "resin is the important factor in the hard pines * * * A block of longleaf pine 2 in. on a side, containing 18 per cent of resin, was sawed in two across the grain. Half of it was boiled in benzole and after the removal of the resin the benzole was driven off. Both pieces were cultivated in contact with wood containing living dry rot fungus. At the end of a year the specimens were dried and weighed. That from which the resin had been removed had lost 8 per cent in weight, the other only 2 per cent." This is in accordance with Mayr ('94), who has said that of two blocks having the same specific gravity, but the one resinous and the other not, the resinous will be the more resistant. However, when we consider the variableness in weight of samples of the same species of wood the value of Hoxie's experiment may be questioned.

Hoxie's specification of "not less than 4 per cent resin" was based on "the percentage of resin in the sound centers of rotted beams taken from a mill." This resin content "was determined in order to get an idea of the amount required to stop fungous growth under ordinary mill conditions. In rotted beams of the poorest of hard pine there is generally a sound center which contains more resin than the remainder of the section. Sometimes it is not bounded by the growth of rings, but is very irregular, the cause being that resin has been irregularly deposited in the section owing to knots or injuries to the tree. The limits of the sound centers are frequently not the same as those of the heartwood." In these cases Hoxie found that the limiting amount of resin which is just sufficient to stop the fungus is in the neighborhood of 3 per cent. Further, *"The limiting power of resin is undoubtedly not absolute* but varies with the moisture, variety of fungus and time of exposure. Therefore, it is safe to assume that a mill beam should have not less than 5 per cent of resin throughout successfully to withstand fungus under ordinary conditions of dampness and allowing a reasonable factor of safety."

While Hoxie has considered that the irregularity of the limits of the sound centers described above is due to the irregular distribution of resin, he has said nothing of the cracks in the beams due to seasoning. It has been the experience of the writer that fungus decay generally proceeds farther toward the pith of a timber along such seasonal cracks. This may also account for an irregular decay.

Another factor which Hoxie ('14) has considered is the relation of relative humidity of the air to fungous decay. He says: "Wood will become dryer or wetter in proportion to the relative humidity of the air; . . . Moreover, the susceptible varieties absorb moisture more rapidly than those which are more resistant to fungi."*

In answer to an article by von Schrenk ('16) on the grading of yellow pine, Hoxie ('16) produces a plate showing the cross-sections of three planks of yellow pine heartwood upon which *Merulius lacrymans* had grown for three years under identical, favorable conditions of moisture and temperature. The decay was greatest in that plank having the lowest specific gravity and at the same time the lowest resin content; and the plank having the highest specific gravity and the highest resin content was most resistant to decay. This is another example to substantiate the conclusions of Mayr ('94), cited above. Although Hoxie attributes the resistance of the heaviest plank to its resin content, it is impossible for the writer to draw the same conclusion, for this resistant plank, besides having the highest resin content of the three, had also a higher specific gravity and narrower growth rings than the other two planks.

Since the specific gravity of wood is to a more or less extent a function of the percentage of the summer wood (Johnson, '93, p. 27) contained, and since the density of wood and the breadth of the growth rings have been so closely related in the grading of coniferous timber, the limited literature dealing with these several properties of wood will be taken up as a whole.

Density has long been held as an index of the durability of wood. As early as 1818 McWilliams (1818, pp. 182-183) said that "from the experience of those most deserving of notice it appears that the durability of timber is in proportion to its solidity." He later defines "solidity" in the following manner: "When different sorts of timber are equally dry, the respective depths to which they will sink in water is a very good criterion of their proportionate solidity."

Mayr ('86), in a discussion of various species of pine, concludes that the wood which is heavier, although less resinous, is more valuable and durable. Later ('94) he has shown that the resin content does not markedly influence the specific weight of the wood, and he states that the more heavily lignified cell walls of the summer wood offer a mechanical resistance to the growth of fungous mycelia, whether resinous or non-resinous.

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*Experiments to determine the optimum relative humidity of the air for the growth on, and the attack of, yellow pine wood by several wood-destroying fungi will be prepared by the writer. The relation of the relative humidity of the air to the absorbing power of various species of yellow pine will be a preliminary consideration.

Von Schrenk ('01), in connection with the description of the decay of *Robinia Pseudacacia* produced by *Fomes rimosus,* says: "The manner in which fungus hyphae spread through a piece of timber is determined to some extent by the structure of the timber. Wood which has large vessels, prominent medullary rays, resin channels, or the wood elements of which are large-lumened and thin-walled, will be penetrated throughout its entire mass more readily than wood where those natural channels are absent, or which has short, thick-walled elements. . . . Growth directly through a solid mass of wood rarely takes place, and when it does so it is a very slow process." Practically the same idea is conveyed by Buller ('06) and Bayliss ('08).

On the relative decay in summer wood and spring wood Falck ('09) says that in cultures of *Lenzites spp.* which attack coniferous wood, the culture blocks show spots of incipient decay in two or three months. These spots occur in the spring wood, and then with an increase of the incubation period may spread to the summer wood or may not, although the whole block is covered with the weft of mycelium. The spring wood is thus destroyed more readily than the summer wood. He noticed this especially in cultures on blocks of *Pinus sylvestris* where the summer wood appeared to be fully intact, while the layers of spring wood had become disintegrated and upon drying cracked into cubes (shown in his pl. IV, fig. 2). This same description of the decay and the relation of summer wood and spring wood to resistance to attack by *Lenzites saepiaria* is reported by Spaulding ('11, p. 21).

The idea previously held throughout the literature, and likewise the result of experience, has been that the sapwood is more readily attacked by fungi than the heartwood because of the richer store of available food material in the former. On the other hand, the relative durability of the sapwood and heartwood depends entirely upon the decay-producing organism and the species of wood attacked. For instance, some fungi will destroy the heartwood and leave the sapwood practically untouched, while others may decay only the sapwood, or both. Falck ('09) points out that *Lenzites abietina* and *L. thermophila* attack the sapwood, while in cultures set up in the same, *L. saepiaria* will decay both the sap- and the heartwood. Hartig ('02, p. 44) has shown that the sapwood of *Pinus sylvestris* (Kiefernholz) is attacked by *Merulius lacrymans* more readily than the heartwood, while the heartwood of *Picea excelsa* (Fichtenholz) is more readily decayed by the same organism than the sapwood. These are striking examples of the specificity of certain organisms, and indicate how the chance of infection of wood may vary with circumstances.

Hoxie ('15, p. 60) has taken these results obtained by Hartig, and on the basis of average resin analyses made by Mayr ('94) has concluded that this difference of resistance in the two species of wood is due to their resin content. However, since resin is so variable within the same species of wood, the analyses made by Mayr could hardly be considered compatible with decay experiments conducted by Hartig on different samples, although for the sake of argument there does seem to be a relation. This, nevertheless, could not apply to the resin in the sapwood if we accept the results of Mayr ('94, p. 70), who shows that fungi thrive on resin in the liquid state as it is found in the sapwood.

Humphrey ('16) has started a series of laboratory tests on the durability of American woods, the first of which reports the decay of various species of conifers induced by *Lentinus lepideus* Fr. Before the experiments were set up the test blocks were weighed, but no record was kept of their relative specific gravity, percentage of summer wood, resin content, etc. The test blocks were allowed to decay for intervals of 4, 6, and 12 months, and it is interesting to notice that after 12 months the sapwood and heartwood of longleaf pine were reduced in weight more than those of shortleaf. Humphrey says that "the specimen of longleaf pine, which did not appear very highly resinous, did not prove as resistant (51.1 per cent reduction) as shortleaf pine (20.7 per cent reduction), which was of a good grade." Since these tests are on one sample block of each species of wood and their relative densities are not reported, it is with considerable hesitation that we would compare thereby the relative resistance of the various species of wood tested. Nevertheless, in the case of longleaf and shortleaf pines it shows that in some cases, at least, shortleaf is more resistant than longleaf.

METHODS OF EXPERIMENTATION.

Samples of wood of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*) were secured from the Julius Seidel Lumber Co., St. Louis, and longleaf pine and loblolly pine (*P. Taeda*) from the John L. Roper Lumber Co., New Berne, N. C. The samples were numbered from 1 to 45. The cross-sections of 1-42 are shown in plates 10 and 11. Samples 1-11 and 43-45 were *P. echinata* from southern Missouri, 12-19 were *P. palustris* from Mississippi, 20-30 were *P. Taeda* from North Carolina, and 31-42 were *P. palustris* from North Carolina. The samples were selected in the lumber yards with only a cursory examination of the various physical factors to be investigated. In this way a wide range of these factors were obtained.

Each sample was cut into culture blocks 1 x 1 x 2 inches, as shown in fig. 1. First, the end of each of the samples was marked off into one-inch squares, and each of these squares was labeled with a letter, beginning alphabetically as near the pith as possible. (In fig. 1 the circle between A and C represents the pith.) With this system of lettering each letter represents a column of culture blocks a certain distance from the pith; thus, in the label M 1101, M represents the position of the column of culture blocks, 11 represents the number of the whole sample, and 1 the number of the first block from the top in the column. Each culture block was labeled with a soft lead pencil, this proving to be the most satisfactory method of labeling.

After the culture blocks were sawed and labeled they were placed in an oven at 65° C. and dried to a constant weight and then weighed in grams, accurately to the second decimal, and estimated to the third. The period of time for kiln-drying to constant weight proved to vary according to the porosity of the wood, the lighter wood drying in 3 to 4 days, the heavier in 6 to 7 days.

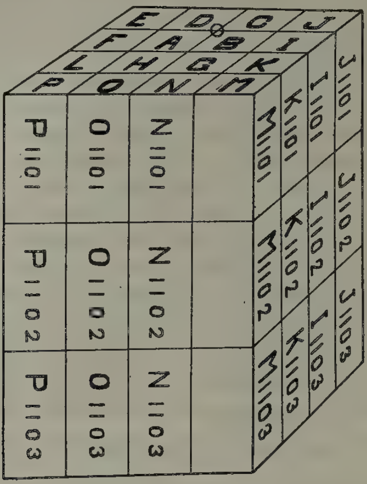

Fig. 1.

After the weights were obtained, the volumes of the culture blocks were determined by immersion in mercury. A graduate cylinder calibrated to 2-cc. divisions was cut off, so that, when filled with mercury up to within 2.5 inches of the top, blocks could be inserted and removed with ease. This method is sufficiently accurate and practicable where a large quantity of volume determinations are to be made. Its main inaccuracy lies in the large surface of mercury exposed where the reading is taken. The volumes were taken in cubic centimeters. From the weight and volume obtained the specific gravity was determined for the individual culture blocks.

The percentage of summer wood was determined for each column of blocks in a sample by measuring in millimeters the width of the layers of summer wood on a radial line 2.5 cm. long and multiplying this value by four. These measurements were made on a smoothly planed cross-section of the whole sample. The value for percentage of summer wood cannot be considered absolute. It will be noticed that even within the individual columns of culture blocks the specific gravity may vary considerably. At first it was thought that this might be due to error in determining the specific gravity, but upon examination of the individual blocks it was found to be due to another cause. It is difficult while rip-sawing a sample to follow the grain of the wood exactly. Thus, whenever the lengthwise sawing is at all oblique to the grain, there is a change in the apportionment of summer wood for the neighboring blocks, changing the specific gravity proportionately.

The number of growth rings per inch were counted on the same radial line as was used to determine the percentage of summer wood. The distance of the culture block from the pith was taken as the distance in inches from the center of the culture block to the pith. If the sample did not contain the pith the location of the latter was determined from the average curvature of the annual rings.

One resin analysis was made for each column of culture blocks, a block of an average specific gravity for the column being used. The samples to be analyzed for resin were kiln-dried at 65° C. until they reached constant weight. They were then removed to a desiccator to cool to room temperature, after which they were planed into fine shavings, which were stored in stoppered bottles until used. Five-gram quantities of shavings were used for each analysis. The shavings were placed in the upper chamber of a Soxhlet extraction apparatus which contained enough glass wool to prevent them from siphoning off when the chamber was emptied automatically. The solvent for extraction was benzol, and the extraction was continued for 36 hours for each sample. Small Westinghouse electric disc stoves of 1.8 amperage were used to keep a constant heat. After extraction the benzol containing the resin was distilled, and the resin transferred to a tared watch-glass, and the contents dried to constant weight in an electric oven kept at 60-65° C. The resin percentages given in table 1 are based on the total hard resin thus extracted and dried.

Preparation of Cultures.

For cultures wide-mouthed jars of one quart capacity were used. In the bottom of each jar there was placed a ¾-inch layer of macerated paper, the well-known Scott's toweling being employed for this purpose. This paper had previously been soaked in distilled water for several hours to remove all readily soluble chemical compounds. After this it was squeezed out, then again rinsed in distilled water, and finally squeezed out until fairly dry before being placed in the jars. Upon this layer the blocks were placed on end, as can be seen in plate 9. The jars were plugged with cotton and sterilized.

Sterilization.

The jars were sterilized in an autoclave for 45 minutes at 20 pounds pressure. Tests were conducted on sterilizing the cultures when they contained sufficient water for inoculation and when no water was added. It was found that some of those sterilized in a wet condition lost resin by steam distillation, and that the resin was not lost by sterilization if the blocks were dry and placed in a dry jar, although sterilized in steam in an autoclave. The loss of resin proved to occur when the blocks contained more than 17.6 per cent resin. There is a criticism, however, of any method of sterilization by heat when wood containing resin is concerned. Heat will necessarily rearrange the resin from the condition in which it naturally exists in wood. This is probably the greatest error in the present preliminary work along this line of investigation.

Tests on the effect of sterilization on the lignin elements were conducted. It was found that thin shavings of wood in water autoclaved for one hour were not delignified to such extent that by staining with zinc chloriodid any change could be detected, although the water in which the shavings had been boiled gave a very faint pink color with phloroglucin and hydrochloric acid. Potter ('04) believed that any method of sterilizing with heat considerably altered the lignin of wood. His tests were made on very young wood, however. Spaulding ('06) repeated Potter's tests and found that it takes 15 to 40 hours of sterilizing at 100° C. to effect any change in the wood elements.

INOCULATION.

After the jars were sterilized the cultures were moistened by adding sterile distilled water, and then were inoculated with *Lenzites saepiaria.* In a previous paper methods of obtaining pure cultures and the propagation of the fungus on various media—Thaxter's potato-hard agar, pine sawdust, and blocks of pine wood—have been described in detail. Agar was found to be the best medium to employ in growing the fungus to be transferred to these block cultures. The fungus produces oidia very readily on agar. Small fragments of the agar containing the fungous mycelium were transferred either to the tops or bases of the culture blocks and so placed that a nocule came in contact with each block. In the first inoculations, where the water was not yet wholly taken up by the blocks and paper, the nocules floated, and when the jars were moved the oidia were scattered; thus in a few days some blocks were covered with a mycelium, while in others the mycelium was merely growing out from the nocules. Therefore, the methods of inoculating were changed, the oidia being scattered over the surface of the blocks by agitating the water introduced into the jars immediately after inoculation.

The cultures were incubated for one year, a part of the time at room temperature and a part of the period in a very humid rotting-pit at a temperature varying from 22° C. in summer to 30-35° C. in winter when the steam heat could be utilized. The jars were watered from time to time so as to keep the paper beneath the culture blocks damp and the relative humidity of the air within the jars approximately 100 per cent.

In all experiments reported in this paper the criterion on which fungous decay is based is the loss in weight during incubation. Thus, when the culture blocks were removed from the jars after one year, they were placed in an oven at 65° C. and again dried to constant weight before final weighing. A control on loss of weight due to sterilizing was arranged. Twenty-five blocks were dried, weighed, and sterilized, and then again dried and weighed, but, as stated above, there was no loss in weight unless the percentage of resin was above 17.6 per cent.

Description of Culture Series.

Four series of cultures were prepared, and they have been designated, respectively, series A, B, C, and D.

SERIES A.

In series A culture blocks of longleaf pine (*Pinus palustris*), shortleaf pine (*P. echinata*), and loblolly pine (*P. Taeda*) were used in their natural conditions and placed in jars as described above and inoculated with *Lenzites saepiaria*. Approximately 2500 culture blocks were prepared for this series, but the results given in table I are taken on 743 blocks of *P. palustris,* 594 blocks of *P. echinata,* and 321 blocks of *P. Taeda,* or a total of 1658. These were incubated for one year. Some of the remainder of the series were left in culture for a two-year period, while others were used in work to show the relation of the oxygen and water content of the substrate to the growth of *Lenzites saepiaria,* as previously reported (Zeller, '16). In the following table the resin percentage, percentage of summer wood, number of rings per inch, and distance from the pith are values for each lettered column of blocks in a sample. Whenever any of these factors are correlated with specific gravity or the percentage loss in weight, as in the plotted charts described below, the average values of the latter for any one lettered column are used.

TABLE I (Series A)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I Culture block	II Volume (cc.)	III Weight before decay (gm.)	IV Specific gravity	V Weight after decay (gm.)	VI Per cent loss in weight due to decay	VII Per cent resin	VIII Per cent summer wood	IX Number growth rings per inch	X Inches from pith	XI Average specific gravity	XII Average per cent loss in weight
Shortleaf pine (*Pinus echinata*)											
A 101	29.	17.962	.620	17.959	.016	16.37	17.5	15.0	.75	.660	4.735
A 102	29.8	19.32	.648	18.095	6.34						
A 103	29.8	23.18	.778	20.501	11.59						
A 104	29.3	18.217	.621	17.455	4.18						
A 107	30.0	19.019	.633	18.725	1.55						
B 101	25.7	15.392	.600	14.998	2.56	23.3	10.0	10.0	.75	.620	2.51
B 102	26.1	16.149	.618	15.690	2.84						
B 103	26.3	16.684	.634	16.190	2.96						
B 105	26.5	16.496	.622	16.175	1.94						
B 106	26.3	16.502	.627	16.13	2.25						
C 101	29.0	19.042	.656	18.455	3.08	17.1	30.0	15.0	1.50	.678	3.06
C 104	30.0	20.155	.671	19.710	2.21						
C 105	29.5	20.150	.683	19.580	2.82						
C 106	28.5	19.717	.692	19.025	3.51						
C 107	28.9	19.948	.690	19.215	3.67						
D 101	27.5	17.490	.635	17.488	0.01	30.5	35.0	13.0	1.50	.671	3.88
D 102	27.5	18.130	.659	17.459	3.71						
D 103	27.7	18.854	.681	18.091	4.05						
D 104	27.6	18.153	.658	17.478	3.72						
D 105	27.9	18.652	.668	17.912	3.97						

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
Shortleaf pine (*Pinus echinata*)											
D 106	27.9	18.926	.678	17.940	5.21						
D 107	26.9	19.378	.720	18.124	6.47						
E 101	28.5	22.730	.797	21.976	3.32	34.2	30.0	14.0	2.50	.902	7.728
E 102	30.0	25.690	.856	23.780	7.43						
E 103	31.4	29.123	.927	26.560	8.80						
E 104	32.0	30.867	.964	27.800	9.93						
E 105	31.9	30.801	.966	27.980	9.16						
F 101	29.0	18.116	.624	17.610	2.79	33.9	30.0	13.0	2.50	.682	5.97
F 102	30.3	19.187	.633	18.386	4.17						
F 103	31.4	20.094	.639	19.067	5.11						
F 104	31.0	20.590	.664	19.451	5.53						
F 105	31.9	23.118	.724	21.317	7.79						
F 106	31.2	25.187	.807	22.560	10.44						
G 101	27.0	18.456	.684	17.620	4.53	24.4	32.0	12.0	2.0	.710	3.73
G 102	27.0	18.671	.692	18.000	3.60						
G 103	27.0	19.189	.711	18.600	3.07						
G 104	26.5	19.160	.723	18.515	3.31						
G 105	27.9	20.618	.739	19.760	4.16						
H 101	26.5	24.931	.941	22.048	11.57	26.9	32.0	12.0	2.75	.838	8.45
H 103	26.8	22.285	.832	20.480	8.10						
H 104	26.0	20.874	.803	19.265	7.70						
H 105	26.0	20.206	.777	18.910	6.42						
A 203	31.5	13.708	.435	12.740	7.06	1.0	10.0	13.0	.75	.460	4.27
A 204	32.0	13.923	.435	13.390	3.82						
A 205	30.7	15.276	.497	14.755	3.42						
A 206	31.8	14.846	.467	14.800	.31						
A 207	31.8	14.196	.447	13.170	7.24						
A 208	31.9	15.325	.480	14.750	3.75						
B 207	35.0	14.768	.422	14.092	4.58	1.8	15.0	15.0	1.50	.423	4.67
B 208	33.5	14.179	.424	13.507	4.75						
C 201	29.7	13.705	.461	13.440	1.93	0.6	20.0	15.0	1.75	.461	3.07
C 202	29.5	13.650	.463	13.295	2.60						
C 203	31.5	14.609	.464	14.203	2.78						
C 204	31.2	14.564	.467	14.298	1.83						
C 207	29.7	13.480	.454	12.938	4.02						
C 208	28.0	12.828	.458	12.150	5.29						
D 201	30.0	13.782	.459	13.510	1.97	1.4	15.0	15.0	2.25	.455	1.70
D 202	30.0	13.580	.453	13.421	1.17						
D 203	31.2	14.132	.453	13.973	1.12						
D 204	32.0	14.719	.460	14.528	1.30						
D 207	30.5	14.034	.460	13.793	1.72						
D 208	31.0	13.935	.449	13.530	2.91						
E 203	30.0	13.187	.439	13.071	0.88	1.5	20.0	11.0	2.75	.442	2.17
E 204	31.0	13.569	.437	13.368	1.48						
E 205	31.8	14.093	.443	13.811	2.00						
E 206	31.3	13.986	.446	13.376	4.36						
E 207	31.5	13.791	.437	13.418	2.72						

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Shortleaf pine (*Pinus echinata*)											
E 208	32.0	14.397	.450	14.171	1.57						
† F 203	30.1	13.680	.454	9.773	28.6	2.0	15.0	13.0	3.0	.455	12.04
† F 204	30.3	13.815	.456	12.867	6.86						
† F 205	30.2	13.731	.455	13.426	2.22						
† F 207	32.0	14.603	.457	13.064	10.5						
A 301	30.7	20.190	.657	19.520	3.32	4.8	16.0	15.5	1.0	.653	6.12
A 302	30.0	18.986	.633	17.841	6.03						
A 303	31.0	20.665	.666	19.070	7.71						
A 304	30.6	19.863	.649	18.814	5.28						
A 305	30.5	20.573	.674	18.900	8.14						
A 306	30.0	19.340	.645	17.804	7.95						
A 307	30.1	19.497	.647	18.639	4.41						
B 301	28.4	18.893	.665	18.492	2.12	2.8	16.0	18.0	0.75	.665	2.12
† C 301	29.7	20.630	.695	18.001	12.74	3.3	30.0	16.0	2.50	.705	11.73
† C 302	31.5	21.850	.694	19.529	10.61						
† C 303	30.0	20.884	.696	18.573	11.08						
† C 304	31.2	21.730	.696	19.611	10.21						
† C 305	30.5	21.930	.719	18.490	9.75						
† C 306	30.0	21.705	.724	18.987	12.51						
† C 307	30.0	21.421	.714	18.155	15.25						
† D 301	27.0	17.364	.643	14.525	16.3	2.5	30.0	17.0	1.75	.658	22.3
† D 302	27.5	17.940	.653	14.245	20.6						
† D 303	29.5	19.135	.648	13.115	31.4						
† D 304	29.0	19.086	.658	14.325	25.0						
† D 305	29.0	19.310	.666	15.105	21.8						
† D 306	28.0	18.965	.677	15.055	20.6						
† D 307	28.0	18.651	.666	14.853	20.4						
† E 301	27.2	18.830	.692	18.170	3.51	3.2	30.0	18.0	1.75	.686	5.69
† E 302	28.0	19.299	.689	18.109	6.16						
† E 303	29.5	19.980	.677	18.560	7.11						
† E 304	29.2	20.075	.688	18.453	8.09						
† E 305	29.0	19.825	.684	19.117	3.57						
* F 302	27.8	17.334	.623	14.299	17.51	2.1	30.0	20.0	2.25	.624	17.68
* F 303	28.0	17.610	.628	14.380	18.34						
* F 304	28.1	17.990	.640	14.616	18.75						
* F 305	27.9	18.034	.646	15.130	16.10						
A 401	31.5	21.232	.675	20.490	3.49	3.6	50.0	10.0	2.25	.691	3.69
A 402	30.5	21.035	.690	20.185	4.04						
A 403	30.5	21.280	.698	20.712	2.67						
A 404	30.5	21.270	.698	20.591	3.19						
A 405	30.7	21.283	.693	20.650	2.97						
A 406	30.0	20.786	.693	19.665	5.40						
A 407	30.0	20.784	.693	19.929	4.11						
B 401	29.0	19.519	.673	18.652	4.44	2.8	55.0	8.0	2.5	.688	5.15
B 402	28.5	19.617	.688	18.512	5.64						
B 403	30.7	21.150	.688	20.016	5.37						
B 404	30.0	20.165	.672	19.198	4.80						
B 405	30.2	20.930	.693	19.803	5.39						
B 406	30.5	21.280	.698	20.193	5.11						
B 407	31.0	21.838	.705	20.683	5.29						
C 403	29.5	21.520	.730	21.157	1.69	1.9	50.0	11.5	3.25	.719	7.38
C 404	30.5	20.161	.726	18.200	9.74						
C 405	29.2	19.131	.709	17.865	6.57						
C 406	29.8	20.091	.721	18.220	9.31						

* Sap-wood.

† Partially sap-wood.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
Shortleaf pine (*Pinus echinata*)											
C 407	30.5	20.295	.711	18.343	9.60						
D 401	32.0	20.71	.710	19.634	5.20	2.0	45.0	11.0	3.25	.702	5.63
D 402	31.5	21.415	.708	20.060	6.33						
D 403	31.2	20.199	.711	18.663	7.61						
D 404	31.5	21.662	.688	21.427	1.08						
D 405	31.0	19.470	.692	17.930	7.91						
E 401	31.0	22.465	.725	22.421	.196	3.55	35.0	10.5	3.5	.746	5.63
E 402	31.0	23.480	.757	22.000	6.30						
E 403	30.5	23.170	.760	21.460	7.39						
E 404	31.0	23.414	.755	22.000	6.04						
E 405	31.7	23.251	.733	21.340	8.21						
F 401	30.5	19.115	.627	18.410	3.69	2.0	60.0	5.0	4.0	.686	4.67
F 402	30.0	19.945	.665	18.830	5.58						
F 403	30.2	20.650	.684	19.645	4.84						
F 404	30.5	20.735	.679	19.760	4.71						
F 405	31.0	21.620	.698	20.730	4.12						
F 406	30.7	22.030	.718	21.060	4.40						
F 407	31.0	22.799	.735	21.610	5.21						
† A 501	30.0	15.216	.507	14.925	1.91	5.4	12.0	13.0	.75	.533	4.42
† A 502	29.5	17.660	.598	17.056	3.42						
† A 503	29.5	17.810	.604	17.104	3.96						
† A 504	30.0	14.828	.494	14.484	2.32						
† A 507	28.0	12.949	.463	11.584	10.50						
† B 501	30.0	13.976	.466	12.251	12.30	12.9	12.0	13.0	.75	.483	13.05
† B 502	30.5	14.755	.484	12.560	14.90						
† B 503	30.5	14.120	.463	12.187	13.70						
† B 505	29.5	14.440	.489	12.318	14.60						
† B 506	30.0	15.474	.516	13.965	9.75						
† C 501	30.0	14.205	.473	13.212	7.00	5.3	12.0	11.0	.75	.468	13.71
† C 502	30.0	14.350	.478	12.300	14.30						
† C 503	29.5	13.778	.467	12.406	9.97						
† C 504	29.5	13.670	.463	11.596	15.18						
† C 505	28.5	14.097	.494	12.180	13.60						
† C 506	28.5	13.534	.475	11.410	15.70						
† C 507	27.5	11.725	.426	9.354	20.20						
† D 501	30.	13.435	.448	12.914	3.88	16.7	12.	10.	.75	.458	4.12
† D 502	30.	13.560	.452	12.904	4.84						
† D 503	30.	13.709	.457	13.142	4.14						
† D 505	28.5	13.600	.477	13.105	3.64						
* E 501	30.	12.670	.422	12.272	3.14	1.4	10.	9.	1.5	.424	4.01
* E 502	30.	12.780	.426	12.239	4.24						
* E 503	30.	12.689	.423	12.256	3.42						
* E 504	30.	12.620	.421	12.051	4.51						
* E 505	30.	12.445	.415	11.972	3.80						
* E 506	30.	13.322	.444	12.676	4.85						

* Sap-wood.

† Partially sap-wood.

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Shortleaf pine (*Pinus echinata*)											
* E 507	30.5	12.690	.416	12.166	4.13						
* F 501	30.	12.580	.419	8.494	32.5	2.1	9.	12.	2.	.424	25.36
* F 502	28.5	12.208	.428	10.080	17.45						
* F 504	31.0	13.259	.427	9.620	27.4						
* F 505	30.5	12.970	.425	9.558	26.35						
* F 506	30.5	12.920	.424	9.932	23.10						
* G 501	29.	12.243	.422	11.500	6.06	1.9	9.	9.	1.5	.422	6.68
* G 502	28.	11.897	.424	11.050	7.13						
* G 504	30.	12.775	.426	11.700	8.42						
* G 505	30.	12.668	.422	11.850	6.46						
* G 507	29.	11.993	.414	11.350	5.36						
* H 501	29.	12.283	.423	11.670	5.00	1.7	8.	8.	1.5	.426	8.29
* H 502	27.	11.424	.423	9.830	13.95						
* H 503	29.5	12.638	.428	11.062	12.48						
* H 504	30.	12.859	.428	12.475	2.99						
* H 505	29.5	12.634	.428	11.746	7.03						
* I 501	28.	12.440	.444	11.100	10.77	1.5	8.	19.	2.	.437	7.60
* I 502	27.5	12.040	.438	11.345	5.77						
* I 503	27.5	11.903	.433	11.146	6.36						
* I 504	28.5	12.320	.432	11.395	7.50						
* J 501	30.	12.895	.429	11.773	8.70	2.4	8.	16.	1.5	.414	7.22
* J 502	28.5	11.970	.420	11.092	7.33						
* J 503	28.	11.535	.412	10.770	6.64						
* J 504	28.	11.387	.407	10.680	6.22						
* K 501	30.	19.459	.648	18.400	5.45	1.7	8.	17.	1.5	.476	3.27
* K 502	30.	13.111	.437	12.550	4.27						
* K 503	29.5	12.110	.411	11.955	1.28						
* K 504	30.5	12.535	.411	12.274	2.08						
* L 501	30.	13.671	.456	10.610	22.4	1.5	8.	21.	2.0	.446	13.58
* L 502	28.5	12.445	.437	10.660	14.3						
* L 504	30.5	13.156	.431	11.720	10.9						
* L 505	30.5	13.465	.441	12.020	10.7						
* L 506	31.	14.414	.465	13.027	9.62						
* M 501	28.	12.207	.436	11.970	1.94	1.8	8.	13.	1.5	.459	2.07
* M 502	28.	12.305	.439	12.100	1.66						
* M 503	27.	13.569	.502	13.215	2.61						
* N 501	28.5	12.036	.422	11.500	4.46	1.5	9.	12.	1.5	.427	4.72
* N 502	28.	11.977	.428	11.521	3.82						
* N 503	27.	12.640	.468	11.850	6.25						
* N 504	28.25	11.705	.414	11.341	3.11						
* N 505	29.5	12.197	.413	11.436	6.25						
* N 506	29.5	12.455	.422	11.856	4.81						
* N 507	28.5	12.030	.422	11.387	5.34						
* O 502	31.	12.985	.418	9.645	25.7	1.4	10.	13.	2.	.426	25.35
* O 503	30.5	13.005	.426	11.235	13.6						
* O 504	31.5	13.373	.424	6.973	47.87						
* O 506	32.	13.716	.429	9.950	27.4						
* O 507	31.5	13.647	.433	11.975	12.20						
* P 501	28.5	24.610	.863	21.820	11.30	1.5	9.	9.	1.5	.450	28.80
* P 502	29.5	17.925	.607	14.270	20.40						
* P 503	29.	12.292	.424	8.900	27.60						
* P 504	30.	12.870	.429	8.520	33.80						
* P 505	30.	12.355	.412	7.510	39.20						
* P 506	30.	12.345	.411	9.300	24.70						
* P 507	30.3	12.747	.421	9.260	27.40						

* Sap-wood.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
					Shortleaf pine (*Pinus echinata*)						
A 601	31.5	21.520	.683	19.639	8.74	1.9	28.3	11.	1.	.574	5.05
A 602	32.	18.651	.583	17.670	5.26						
A 603	32.	19.165	.599	17.979	6.19						
A 604	31.	16.328	.527	15.994	2.04						
A 605	30.5	16.082	.527	15.602	2.98						
A 606	31.5	16.648	.528	15.775	5.24						
A 607	31.5	18.552	.589	17.637	4.93						
A 608	30.25	16.805	.556	15.960	5.03						
B 601	30.	17.005	.567	16.477	3.11	4.1	28.3	8.5	1.0	.563	5.96
B 603	31.	18.695	.603	17.420	6.83						
B 605	30.5	16.455	.540	15.815	3.89						
B 606	30.	15.574	.519	15.272	1.94						
B 607	28.5	17.510	.614	16.603	5.18						
B 608	29.5	15.843	.537	13.502	14.80						
C 601	30.	16.650	.555	15.920	4.38	2.1	30.	7.0	2.0	.548	3.40
C 602	30.5	16.720	.548	16.319	2.4						
C 603	30.	16.500	.550	15.846	3.96						
C 604	30.	16.710	.557	16.230	2.87						
C 605	30.	16.065	.535	15.542	3.26						
C 606	29.5	15.758	.534	15.147	3.88						
C 607	29.5	16.393	.555	15.856	3.28						
C 608	28.5	15.645	.549	15.150	3.16						
D 601	28.5	16.110	.566	16.092	.11	8.4	30.	7.0	2.0	.545	1.28
D 605	28.5	15.243	.535	14.997	1.61						
D 606	29.	15.547	.536	15.220	2.11						
E 601	26.5	14.850	.561	14.841	.06	2.6	30.3	7.0	2.0	.554	3.18
E 602	28.5	15.973	.560	15.371	3.77						
E 603	27.5	15.918	.579	15.287	3.96						
E 604	28.5	15.632	.548	15.124	3.25						
E 605	28.5	15.067	.528	14.876	1.27						
E 606	27.5	14.784	.537	14.172	4.14						
E 607	28.	15.752	.562	14.990	4.83						
E 608	28.	15.487	.553	14.847	4.14						
F 601	28.	15.180	.542	14.830	2.31	4.9	31.	8.	2.5	.529	1.86
F 603	27.	14.370	.532	14.121	1.73						
F 605	27.	14.081	.521	13.845	1.68						
F 606	27.5	14.485	.526	14.400	.58						
F 607	28.5	14.935	.524	14.590	2.31						
F 608	27.25	14.430	.529	14.062	2.55						
G 601	31.	17.670	.570	17.328	1.94	5.2	31.	11.	3.	.581	3.07
G 602	31.	17.625	.568	17.003	3.52						
G 603	31.	17.380	.561	17.073	1.77						
G 604	29.	15.995	.552	15.742	1.58						
G 605	28.5	15.895	.557	15.666	1.44						
G 606	28.5	15.600	.547	15.255	2.21						
G 607	30.	18.760	.625	17.689	5.71						
G 608	29.5	19.845	.673	18.574	6.41						

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Shortleaf pine (*Pinus echinata*)											
H 601	28.5	16.160	.567	15.982	1.10	2.5	31.	11.0	3.0	.564	1.62
H 602	29.	16.568	.571	16.420	.89						
H 603	30.	17.270	.573	17.054	1.25						
H 604	28.5	16.235	.570	16.023	1.3						
H 605	29.	16.234	.560	15.980	1.56						
H 606	28.	15.338	.548	15.033	1.98						
H 607	28.	15.751	.562	15.309	2.8						
H 608	27.5	15.332	.557	15.012	2.09						
I 601	29.	16.309	.562	15.956	2.16	3.7	32.	12.	3.25	.568	2.79
I 602	28.	15.890	.567	15.430	2.9						
I 603	29.5	16.840	.571	16.327	3.05						
I 604	28.	16.133	.576	15.615	3.21						
I 605	29.5	16.695	.566	16.176	3.11						
I 606	27.5	15.760	.573	15.233	3.34						
I 607	28.5	16.051	.563	15.525	3.28						
I 608	28.	15.829	.566	15.623	1.3						
A 701	30.	15.649	.522	15.601	.31	1.6	24.	13.	2.25	.531	.46
A 702	31.	16.689	.537	16.650	.23						
A 703	30.	15.896	.530	15.782	.72						
A 704	29.5	15.492	.525	15.412	.52						
A 705	28.	14.964	.535	14.856	.72						
A 706	28.5	15.126	.531	15.097	.19						
A 707	28.	14.990	.535	14.914	.51						
B 701	28.5	15.456	.542	15.100	2.3	1.6	25.	13.	3.0	.532	1.87
B 702	29.	15.790	.544	15.482	1.95						
B 703	28.	15.061	.538	14.779	1.87						
B 704	28.2	14.829	.526	14.619	1.42						
B 705	28.	14.640	.523	14.231	2.79						
B 706	29.	15.200	.524	14.982	1.44						
B 707	28.	14.715	.526	14.520	1.33						
C 701	28.5	15.840	.556	15.600	1.51	0.7	25.	13.	3.	.565	2.19
C 702	29.5	16.583	.562	16.150	2.62						
C 703	29.2	16.695	.571	16.260	2.61						
C 704	29.3	16.701	.570	16.320	2.28						
C 705	28.7	16.293	.567	15.980	1.94						
D 701	26.	14.880	.572	13.866	6.82	1.1	24.	16.	3.5	.556	2.47
D 702	27.5	15.147	.551	14.868	1.84						
D 703	28.	15.825	.565	15.577	1.57						
D 704	28.5	15.975	.560	15.755	1.38						
D 705	29.	15.972	.551	15.687	1.79						
D 706	30.	16.376	.546	16.067	1.89						
D 707	28.	15.333	.547	15.026	2.00						
E 701	30.	17.580	.586	16.853	4.13	0.6	24.	19.	3.75	.568	5.28
E 702	31.	18.483	.596	17.685	4.32						
E 703	30.	17.508	.583	17.386	.70						
E 704	29.75	16.762	.564	16.150	3.65						
E 705	29.	16.277	.561	15.434	5.18						
E 706	29.5	16.190	.548	14.328	11.50						
E 707	27.	14.563	.540	13.369	8.20						
F 701	31.	16.232	.524	15.047	7.30	1.2	24.	19.	4.	.531	5.34
F 702	30.	15.947	.532	14.910	6.50						
F 703	29.5	15.707	.532	13.806	12.10						
F 704	28.5	15.179	.532	14.780	2.63						
F 705	28.5	15.191	.533	14.765	2.81						
F 706	30.	15.925	.531	15.423	3.15						
F 707	29.5	15.761	.534	15.303	2.90						

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I Culture block	II Volume (cc.)	III Weight before decay (gm.)	IV Specific gravity	V Weight after decay (gm.)	VI Per cent loss in weight due to decay	VII Per cent resin	VIII Per cent summer wood	IX Number growth rings per inch	X Inches from pith	XI Average specific gravity	XII Average per cent loss in weight
Shortleaf pine (*Pinus echinata*)											
G 701	28.5	15.985	.560	15.984	.01	2.2	24.	21.	4.5	.555	.35
G 702	27.5	15.724	.572	15.685	.25						
G 703	29.	16.335	.563	16.335	.00						
G 704	29.	15.975	.551	15.823	.95						
G 705	29.	15.775	.544	15.746	.18						
G 706	29.	15.861	.546	15.766	.60						
G 707	28.	15.465	.552	15.398	.43						
H 701	28.25	16.102	.570	15.821	1.75	.6	24.	21.	4.25	.559	1.97
H 702	27.	15.598	.577	15.311	1.84						
H 703	28.25	16.108	.570	15.791	1.97						
H 704	29.	16.650	.573	16.612	.23						
H 705	30.	16.286	.543	16.002	1.74						
H 706	30.	16.336	.544	16.107	1.40						
H 707	29.	15.690	.541	15.246	2.83						
I 701	31.	17.441	.562	17.028	2.37	1.4	24.	20.	5.	.544	4.26
I 702	28.2	15.891	.563	15.570	2.02						
I 703	29.9	16.337	.546	16.060	1.69						
I 704	29.1	15.530	.534	15.195	2.16						
I 705	29.8	15.301	.514	13.300	13.08						
A 801	28.	21.995	.785	20.460	6.99	1.9	80.	7.	1.5	.762	5.53
A 802	27.25	20.760	.762	20.072	3.32						
A 803	27.	20.248	.750	18.550	8.39						
A 804	27.	20.253	.750	19.400	4.21						
A 805	26.25	20.005	.762	19.060	4.73						
B 802	29.5	21.400	.725	20.742	3.07	3.4	70.	9.	2.	.730	2.79
B 803	28.25	20.764	.735	20.240	2.52						
C 801	29.	18.609	.642	17.672	5.03	4.6	35.	12.	2.5	.648	5.05
C 802	27.	17.000	.629	16.154	4.98						
C 803	27.5	17.950	.653	16.993	5.33						
C 804	28.	18.115	.647	17.286	4.58						
C 805	26.	16.900	.650	15.966	5.53						
C 806	26.5	17.380	.656	16.587	4.56						
C 807	26.	17.110	.658	16.199	5.32						
D 801	30.	20.272	.676	19.454	4.03	5.5	35.	12.	2.75	.668	4.35
D 802	28.	18.520	.661	17.657	4.66						
E 801	29.5	19.785	.670	19.049	3.72	5.5	32.	12.	2.75	.683	4.21
E 802	29.5	19.710	.668	18.851	4.36						
E 803	28.5	19.380	.680	18.528	3.88						
E 804	28.	19.390	.692	18.543	4.37						
E 805	28.	19.205	.685	18.301	4.66						
E 806	28.	19.363	.692	18.519	4.36						
E 807	28.	19.579	.699	18.776	4.10						
F 801	29.	19.318	.666	18.712	3.14	21.9	32.	14.	3.25	.717	5.66
F 802	28.	18.872	.674	18.000	4.62						
F 803	28.1	20.266	.721	19.332	4.61						
F 804	28.1	21.147	.752	19.500	7.79						
F 805	28.	21.766	.776	20.000	8.13						

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Shortleaf pine (*Pinus echinata*)											
G 801	28.	18.020	.643	18.014	.03	11.7	40.	8.	4.	.727	3.70
G 802	27.5	18.285	.665	18.077	1.14						
G 803	27.	19.349	.716	18.572	4.02						
G 804	27.	20.155	.745	19.191	4.78						
G 805	27.	20.887	.774	19.842	5.00						
G 806	27.5	21.932	.797	20.603	6.06						
G 807	27.5	20.688	.752	19.688	4.84						
H 801	28.5	18.708	.656	18.460	1.33	2.90	38.	12.	3.75	.666	1.81
H 802	27.5	17.501	.636	17.171	1.89						
H 803	27.	17.914	.663	17.357	3.11						
H 804	27.	18.580	.688	18.008	3.08						
H 805	26.5	17.999	.679	17.627	2.08						
H 806	27.5	18.307	.666	18.211	.52						
H 807	27.5	18.647	.678	18.531	.62						
I 801	28.1	18.151	.646	17.072	5.94	5.6	37.	12	3.5	.648	3.01
I 802	27.8	17.930	.645	17.620	1.73						
I 803	28.	18.371	.656	17.940	2.35						
I 804	28.	18.224	.651	17.735	2.68						
I 805	27.2	17.569	.646	17.160	2.33						
A 901	31.5	15.385	.488	15.085	1.95	10.1	23.	7.	1.25	.453	3.14
A 902	31.75	14.320	.451	14.164	1.09						
A 903	31.5	13.940	.443	13.545	2.83						
A 904	31.	13.648	.440	12.984	4.86						
A 905	30.5	13.498	.442	12.823	5.00						
B 901	29.4	14.850	.505	14.702	.99	1.74	23.	10.	2.25	.464	1.28
B 902	28.5	13.357	.468	13.210	1.10						
B 903	28.7	12.925	.450	12.735	1.47						
B 904	29.	12.917	.445	12.710	1.60						
B 905	28.8	12.980	.451	12.820	1.23						
C 901	31.	14.355	.462	14.012	2.39	7.22	23.	11.	2.25	.464	.80
C 902	31.25	14.575	.466	14.524	.35						
C 904	30.75	13.823	.450	13.820	.02						
C 907	31.	14.890	.480	14.822	.45						
D 901	29.	13.740	.474	13.710	.21	.78	22.	12.	2.75	.472	.22
D 902	28.	13.418	.479	13.380	.28						
D 903	28.	13.240	.473	13.214	.19						
D 904	28.5	13.435	.471	13.385	.37						
D 905	28.75	13.670	.475	13.619	.37						
D 906	30.5	14.325	.469	14.307	.12						
D 907	30.	14.000	.467	14.000	.00						
E 902	31.	15.575	.503	14.841	4.71	7.34	23.	12.	3.	.498	3.46
E 903	30.8	15.485	.503	14.689	5.14						
E 905	30.	14.981	.499	14.645	2.24						
E 906	31.	15.382	.496	14.993	2.53						
E 907	30.2	14.821	.491	14.418	2.72						
F 901	30.5	15.102	.495	15.081	.14	.4	23.	11.	3.25	.471	.25
F 902	29.7	14.243	.479	14.122	.85						
F 903	28.5	13.270	.466	13.192	.59						
F 904	28.7	13.310	.464	13.308	.01						
F 905	28.7	13.365	.466	13.352	.09						
F 906	29.5	13.575	.460	13.569	.04						
F 907	28.5	13.400	.470	13.392	.06						
G 901	30.	14.452	.482	14.345	.74	1.94	24.	10.	3.5	.481	1.89
G 902	28.9	13.823	.478	13.538	2.06						
G 903	28.	13.500	.482	13.220	2.08						
G 904	28.6	13.843	.484	13.560	2.04						

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
Shortleaf pine (*Pinus echinata*)											
G 905	29.1	13.954	.479	13.681	1.96						
G 906	29.	13.947	.481	13.651	2.12						
G 907	28.9	13.907	.481	13.596	2.24						
H 901	29.2	14.335	.491	14.070	1.85	1.14	24.	10.	3.5	.487	2.21
H 902	28.7	14.115	.492	13.892	1.58						
H 903	28.	13.685	.488	13.390	2.16						
H 904	29.	14.180	.489	13.761	2.95						
H 905	29.7	14.365	.484	14.111	1.77						
H 906	30.	14.525	.484	14.062	3.19						
H 907	30.5	14.660	.481	14.365	2.01						
I 901	30.4	15.004	.494	14.865	.93	.54	24.	12.	4.25	.487	1.17
I 902	29.3	14.380	.491	14.228	1.06						
I 903	28.2	13.827	.491	13.667	1.16						
I 904	29.6	14.365	.485	14.165	1.39						
I 905	30.	14.592	.486	14.447	1.20						
I 906	30.	14.501	.483	14.333	1.16						
I 907	30.5	14.720	.483	14.526	1.32						
A1001	30.	19.410	.647	18.491	4.74	27.76	20.	17.	1.75	.787	8.58
A1002	30.	20.885	.696	19.711	5.62						
A1003	30.	20.100	.670	18.813	5.91						
A1004	30.	21.670	.722	20.020	7.61						
A1005	29.	26.123	.900	23.175	11.30						
A1006	28.5	28.968	1.016	25.303	12.68						
A1007	28.	24.110	.861	21.176	12.2						
B1001	30.	16.440	.548	16.121	1.94	17.56	20.	14.	1.5	.688	2.51
B1002	30.5	17.456	.572	17.092	2.08						
B1003	30.	17.380	.579	17.320	.35						
B1004	30.	18.717	.624	18.680	.20						
B1005	30.	22.670	.756	22.104	2.49						
B1006	29.5	27.575	.935	26.022	5.63						
B1007	28.2	22.661	.804	21.551	4.90						
C1001	31.	18.490	.596	17.987	2.72	6.12	20.	21.	2.	.599	2.44
C1002	30.5	19.945	.654	19.111	4.18						
C1003	30.	18.040	.601	17.502	2.98						
C1004	30.	17.640	.588	17.419	1.25						
C1005	30.	17.680	.589	17.359	1.82						
C1006	30.	18.025	.601	17.726	1.66						
C1007	29.7	16.730	.563	16.317	2.47						
D1001	28.	14.798	.528	14.757	.28	17.3	21.	22.	2.75	.581	1.41
D1002	28.2	15.240	.540	15.172	.45						
D1003	28.	15.245	.544	15.129	.76						
D1004	28.	15.427	.551	15.313	.74						
D1005	28.	17.479	.624	17.096	2.19						
D1006	28.	17.768	.634	17.467	1.69						
D1007	28.5	18.459	.648	17.768	3.74						
E1001	28.	15.128	.541	14.905	1.47	3.7	24.	23.	2.5	.582	1.77
E1002	28.	15.801	.564	15.630	1.08						

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Shortleaf pine (*Pinus echinata*)											
E1003	27.9	15.705	563	15.546	1.01						
E1004	28.	16.252	.580	15.980	1.67						
E1005	28.7	17.078	.594	16.839	1.40						
E1006	29.	18.225	.628	17.732	2.71						
E1007	28.1	17.109	.609	16.579	3.10						
F1001	29.	16.505	.569	16.496	.05	2.56	24.	23.	2.75	.576	.04
F1002	29.1	16.883	.580	16.883	0.00						
F1003	28.1	16.530	.588	16.520	.06						
F1004	28.5	16.482	.578	16.475	.04						
G1001	29.6	17.092	.576	16.871	1.29	2.2	24.	17.	3.5	.584	1.27
G1002	29.	16.813	.580	16.698	.68						
G1003	28.	16.480	.588	16.265	1.31						
G1004	28.2	16.621	.589	16.338	1.70						
G1005	28.7	16.770	.584	16.611	.95						
G1006	28.4	16.659	.590	16.326	2.00						
G1007	29.	16.856	.581	16.693	.97						
H1001	29.	17.563	.605	17.560	.02	2.14	24.	17.	3.5	.604	.36
H1002	28.5	17.513	.615	17.482	.18						
H1003	28.	16.965	.606	16.792	1.02						
H1004	28.	16.914	.604	16.847	.40						
H1005	28.4	17.251	.607	17.223	.16						
H1006	28.3	17.203	.607	17.185	.10						
H1007	28.2	16.540	.586	16.431	.66						
I 1001	30.3	18.510	.611	18.500	.05	.9	25.	15.	3.75	.607	.68
I 1002	29.8	17.778	.596	17.750	.16						
I 1003	28.2	17.085	.606	16.980	.62						
I 1004	28.3	17.460	.617	17.231	1.31						
I 1007	30.	18.220	.607	17.978	1.33						
A1101	27.5	18.428	.670	17.263	6.31	22.98	16.	14.	.5	.674	5.90
A1102	27.7	18.597	.671	17.392	6.49						
A1103	28.	18.594	.663	17.427	6.27						
A1104	28.7	18.881	.657	17.742	6.03						
A1105	28.	19.837	.708	18.964	4.4						
A1106	28.2	26.795	.950	24.380	9.02						
B1101	28.2	19.295	.684	18.378	4.75	20.32	16.	12.	.5	.666	3.92
B1102	28.	18.223	.652	17.580	3.53						
B1103	27.9	18.525	.664	17.818	3.82						
B1104	29.	19.242	.664	18.560	3.54						
C1101	30.	17.865	.595	17.260	3.39	18.5	16.	13.	.5	.646	3.84
C1102	30.1	17.890	.594	17.740	.84						
C1103	29.9	19.519	.653	18.551	4.96						
C1104	30.5	22.693	.744	21.290	6.18						
D1101	29.5	20.353	.690	18.599	8.62	21.04	16.	17.	.5	.682	8.68
D1102	28.7	19.956	.696	18.279	8.40						
D1103	28.5	19.127	.672	17.789	7.00						
D1104	29.2	19.940	.683	18.131	9.03						
D1105	28.3	19.110	.676	17.383	9.03						
D1106	28.7	19.445	.677	17.498	10.01						
† E1102	28.5	16.715	.587	15.494	7.30	‡14.32	10.	32.	1.5	.526	5.36
† E1103	29.2	15.424	.528	14.250	7.60	* 3.68					
† E1104	30.	14.660	.488	14.398	1.79						
† E1105	30.	15.078	.502	14.360	4.76						

* Sap-wood.

† Partially sap-wood.

‡ Percentage of resin in heart-wood where both heart-wood and sap-wood occur in the same culture block.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
Shortleaf pine (*Pinus echinata*)											
† F1101	28.	13.630	.487	13.106	3.84	‡10.64	11.	35.	1.5	.495	3.34
† F1102	28.4	13.823	.487	13.358	3.36	* 2.5					
† F1103	28.8	13.965	.485	13.380	4.19						
† F1104	29.5	14.045	.476	13.750	2.10						
† F1105	29.	13.836	.477	13.568	1.93						
† F1106	30.	16.875	.562	16.083	4.70						
†G1101	28.5	16.462	.577	14.637	11.10	‡ 8.94	13.	32.	1.5	.539	6.75
†G1102	29.3	15.597	.532	14.593	6.45	* 2.68					
†G1103	29.2	15.276	.523	14.545	4.78						
†G1104	29.	14.577	.503	13.897	4.66						
†H1101	28.	16.190	.578	15.450	4.57	‡25.34	13.	31.	1.5	.551	5.25
†H1102	28.7	16.340	.570	15.260	6.61	* 6.58					
†H1103	28.3	15.070	.532	14.260	5.38						
†H1104	28.2	14.775	.524	14.120	4.44						
† I 1101	28.	13.066	.467	11.665	10.7	‡18.3	12.	31.	1.5	.469	11.6
† I 1102	27.2	12.858	.472	11.470	10.8	* 4.68					
† I 1103	27.8	12.595	.453	11.140	11.5						
† I 1104	28.3	13.690	.483	11.870	13.3						
† J 1101	30.	13.410	.447	11.322	15.5	‡13.38	13.	33.	1.5	.487	12.4
† J 1102	29.5	12.893	.437	10.834	15.9	* 1.88					
† J 1103	29.5	15.535	.527	14.030	9.68						
†J 1104	28.	15.080	.538	13.790	8.55						
†K1101	29.	12.999	.447	9.505	26.9	‡ 2.04	11.	30.	2.	.428	31.8
†K1102	29.	12.466	.430	9.192	26.2	* 1.78					
†K1103	29.25	12.266	.419	7.095	42.1						
†K1104	29.	12.127	.418	8.220	32.2						
† L1101	28.8	12.595	.437	8.990	28.6	1.36	7.	23.	2.	.433	54.3
† L1102	29.5	12.646	.428	5.160	59.2						
† L1103	29.	12.565	.433	4.801	61.8						
† L1104	28.7	12.497	.435	5.271	67.8						
*M110	28.	11.920	.426	3.282	72.4	1.44	6.	15.	2.75	.426	57.1
*M1102	27.5	11.675	.425	5.294	54.6						
*M1103	27.3	11.525	.423	5.763	50.0						
*M1104	28.	12.040	.430	5.808	51.7						
*N1101	28.	12.184	.435	7.996	34.4	1.26	6.	18.	2.5	.433	30.51
*N1102	27.7	12.012	.434	7.870	34.45						
*N1103	28.	11.963	.427	8.220	31.3						
*N1104	28.2	12.306	.436	9.610	21.9						
* O1101	27.7	12.481	.450	8.734	30.	3.56	6.	18.	2.5	.453	21.1
* O1102	27.2	12.334	.454	9.483	23.1						
* O1103	26.7	12.076	.452	10.414	13.7						
* O1104	27.	12.332	.457	10.565	14.3						
* O1105	27.5	12.432	.452	9.045	27.2						

* Sap-wood.

† Partially sap-wood.

‡ Percentage of resin in heart-wood where both heart-wood and sap-wood occur in the same culture block.

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
					Shortleaf pine (*Pinus echinata*)						
*O1106	27.7	12.563	.453	10.219	18.7						
*P1101	27.	12.650	.468	6.330	50.	3.24	6.	13.	2.75	.461	52.5
*P1102	27.5	12.628	.459	5.112	59.5						
*P1103	26.7	12.188	.456	5.146	57.8						
*P1104	27.	12.229	.453	4.885	60.0						
*P1105	27.	12.122	.448	6.163	49.0						
*P1106	29.4	14.151	.482	8.506	39.9						
					Longleaf pine (*Pinus palustris*)						
A1201	30.3	19.512	.644	18.795	3.67	.82	30.	22.	0.75	.656	3.12
A1202	30.	19.246	.641	18.579	3.46						
A1203	30.	19.475	.649	18.818	3.38						
A1204	30.2	19.851	.657	19.267	2.94						
A1205	30.	19.994	.666	19.371	3.12						
A1206	29.3	19.562	.667	18.962	3.07						
A1207	28.5	19.106	.670	18.690	2.18						
B1201	32.	20.360	.636	19.887	2.32	.94	35.	17.	.75	.627	1.81
B1203	31.1	19.681	.633	19.368	1.59						
B1204	31.5	19.838	.630	19.472	1.84						
B1205	31.	19.377	.625	19.050	1.69						
B1207	30.4	18.625	.612	18.322	1.62						
C1201	30.1	21.117	.701	20.870	1.17	1.42	35.	18.	1.5	.699	1.72
C1202	30.	20.967	.698	20.484	2.31						
C1203	30.7	21.647	.706	21.301	1.60						
C1204	30.6	21.632	.707	21.235	1.84						
C1205	30.5	21.433	.702	21.056	1.76						
C1206	30.	20.739	.691	20.509	1.11						
C1207	30.	20.795	.693	20.331	2.23						
D1201	31.	20.124	.648	20.068	.28	1.64	35.	17.	1.5	.655	1.31
D1202	31.3	20.599	.658	20.365	1.13						
D1203	32.	21.307	.666	21.070	1.11						
D1204	32.	20.910	.654	20.410	2.39						
D1205	31.2	20.352	.652	20.020	1.63						
E1201	32.	20.308	.635	20.300	.04	27.84	30.	16.	2.5	.641	8.13
E1202	31.2	19.628	.629	17.310	11.80						
E1203	31.9	20.115	.630	18.240	9.34						
E1204	32.	20.302	.635	18.370	9.52						
E1205	32.3	20.867	.646	18.850	9.64						
E1206	32.1	21.062	.656	19.570	7.09						
E1207	32.6	21.289	.654	19.270	9.48						
F1201	28.	22.718	.811	22.455	1.16	13.54	30.	17.	2.5	.840	6.90
F1202	28.	23.225	.830	21.649	6.78						
F1203	28.8	24.391	.847	22.348	8.39						
F1204	29.3	24.814	.847	22.970	7.43						
F1205	29.4	25.189	.856	22.985	8.74						
F1206	28.9	24.627	.852	22.342	9.28						
F1207	28.	23.536	.840	21.990	6.56						
G1201	31.5	30.702	.974	27.666	9.89	22.14	30.	18.	3.5	.956	10.11
G1202	30.	28.835	.961	25.636	11.10						
G1203	29.9	28.450	.951	25.371	10.80						
G1204	28.7	27.499	.958	24.820	9.74						
G1205	28.6	26.801	.937	24.376	9.05						
H1201	33.7	21.353	.633	21.210	.67	1.48	28.	16.	3.5	.633	.64
H1202	31.	19.308	.623	19.198	.57						
H1204	31.9	20.200	.633	20.090	.55						

* Sap-wood.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
				Longleaf pine (*Pinus palustris*)							
H1206	32.	20.473	.640	20.320	.75						
H1207	32.	20.353	.635	20.222	.64						
I 1201	31.4	31.454	1.000	29.222	7.09	25.26	30.	18.	4.5	1.025	6.63
I 1202	28.3	28.911	1.022	26.600	8.00						
I 1203	30.	30.981	1.030	29.040	6.26						
I 1204	31.	33.061	1.066	31.040	6.11						
I 1207	30.5	30.687	1.006	28.930	5.72						
A1301	31.9	24.630	.772	24.000	2.55	7.04	37.	27.	2.0	.787	1.41
A1302	30.9	24.150	.781	23.900	1.03						
A1303	31.1	24.691	.794	24.410	1.14						
A1304	32.	25.301	.790	24.960	1.35						
A1305	32.	25.504	.797	25.250	1.00						
B1301	31.5	23.882	.758	23.350	2.22	7.42	37.	27.	2.0	.807	3.93
B1302	32.	24.265	.758	23.625	2.64						
B1303	32.7	25.231	.771	24.506	2.87						
B1304	33.1	25.871	.781	25.148	2.79						
B1305	32.	25.921	.809	24.936	3.8						
B1306	32.6	29.638	.909	27.681	6.6						
B1307	31.8	27.549	.866	25.727	6.61						
C1301	32.	23.599	.737	23.310	1.22	2.52	37.	28.	2.5	.728	1.03
C1302	32.1	23.704	.738	23.420	1.20						
C1303	32.3	23.706	.734	23.437	1.13						
C1304	32.	23.596	.737	23.290	1.30						
C1305	31.7	22.825	.720	22.500	1.42						
C1306	32.	23.040	.720	23.056	?0.00						
C1307	31.5	22.392	.711	22.190	.9						
D1301	31.2	23.948	.767	23.301	2.71	2.58	37.	29.	2.5	.760	2.35
D1302	31.3	23.971	.766	23.298	2.81						
D1303	32.	24.448	.764	23.942	2.07						
D1304	31.9	24.151	.757	23.700	1.87						
D1305	32.	23.944	.748	23.398	2.28						
E1301	32.	28.279	.883	26.517	6.23	25.88	39.	30.	3.0	.951	8.45
E1302	32.5	29.872	.919	27.500	7.94						
E1303	33.3	31.460	.944	28.670	8.87						
E1304	32.2	31.152	.967	28.140	9.66						
E1305	32.1	31.644	.985	28.720	9.24						
E1306	33.	32.300	.979	29.500	8.67						
E1307	31.2	30.420	.978	27.810	8.58						
F1301	33.2	22.656	.682	22.230	1.88	4.48	39.	28.	3.0	.667	2.17
F1302	32.2	21.820	.677	21.433	1.77						
F1303	32.	21.269	.663	20.806	2.18						
F1304	32.	21.471	.672	20.974	2.31						
F1305	33.	21.666	.657	21.143	2.41						
F1306	32.9	21.557	.655	21.040	2.40						
F1307	32.2	21.326	.663	20.840	2.28						
G1301	31.	20.421	.659	19.850	2.79	‡6.60	39.	32.	4.	.653	3.48

‡ Percentage of resin in heart-wood where both heart-wood and sap-wood occur in the same culture block.

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Longleaf pine (*Pinus palustris*)											
G1302	31.2	20.569	.658	19.819	3.65	*3.24					
G1303	30.7	20.128	.655	19.315	4.04						
G1304	30.6	20.071	.656	19.339	3.64						
G1305	30.9	20.245	.655	19.519	3.58						
G1306	30.8	20.148	.654	19.492	3.26						
G1307	30.	19.184	.639	18.536	3.38						
*H1301	31.7	18.709	.590	16.479	11.92	2.36	31.	14.	5.	.592	10.04
*H1304	31.8	18.499	.581	16.500	10.80						
*H1305	32.	18.994	.593	17.200	9.44						
*H1306	32.	19.223	.600	17.549	8.71						
*H1307	30.9	18.433	.596	16.710	9.35						
A1401	32.1	17.873	.557	17.360	2.87	3.94	20.	7.5	3.25	.582	3.94
A1402	31.2	17.755	.569	17.120	3.58						
A1403	32.	20.249	.633	19.105	5.65						
A1405	31.8	18.187	.572	17.520	3.67						
B1401	32.	17.513	.547	16.885	3.59	4.88	20.	6.5	3.25	.616	3.66
B1402	31.9	17.943	.563	17.440	2.81						
B1403	32.	23.658	.738	22.572	4.59						
C1401	31.	18.728	.604	18.093	3.39	5.9	20.	7.	3.5	.610	4.69
C1402	32.	19.926	.622	18.780	5.75						
C1403	32.1	19.499	.607	18.653	4.34						
C1404	32.	19.394	.606	18.370	5.28						
D1401	31.9	20.143	.631	19.245	4.47	4.3	22.	8.	3.5	.601	3.63
D1402	32.5	19.496	.600	18.728	3.94						
D1403	32.	18.759	.587	18.260	2.66						
D1404	32.	18.747	.586	18.100	3.45						
E1403	32.	17.613	.550	17.002	3.47	5.22	22.	9.	4.25	.548	3.68
E1404	32.2	17.728	.551	16.997	4.12						
E1405	33.	17.999	.545	17.380	3.44						
F1401	32.	18.885	.590	18.721	.87	5.62	22.	9.	4.25	.596	.91
F1402	32.1	20.137	.627	19.897	1.19						
F1403	32.	19.254	.601	19.132	.63						
F1404	32.1	18.887	.588	18.881	.03						
F1405	31.5	18.412	.584	18.127	1.55						
F1406	31.8	18.596	.585	18.372	1.21						
G1401	31.8	18.403	.578	17.926	2.59	8.66	22.	10.	5.	.576	3.03
G1404	32.	17.953	.561	17.380	3.19						
G1405	31.8	18.245	.574	17.627	3.39						
G1406	32.6	19.334	.593	18.750	3.02						
†H1401	33.1	19.199	.580	17.521	8.74	‡ 5.18	28.	8.	5.	.570	11.77
†H1403	32.9	18.782	.571	16.222	13.63	* 2.32					
†H1404	32.6	18.282	.560	15.914	12.95						
†I 1401	33.5	18.781	.561	14.310	23.8	‡ 8.68	20.	10.5	5.5	.559	18.07
†I 1403	33.8	18.196	.538	14.120	22.4	* 1.98					
†I 1405	31.	17.950	.578	15.981	10.97						
†I 1406	32.7	18.313	.560	15.550	15.10						
A1501	32.7	21.383	.653	21.066	1.48	.76	28.	11.	1.25	.654	1.44
A1502	31.	20.097	.648	19.805	1.45						
A1503	31.4	20.766	.661	20.478	1.39						
B1501	32.	21.361	.667	21.272	.42	.84	28.	9.	1.25	.680	.32
B1502	32.8	21.807	.665	21.740	.31						
B1503	33.5	22.638	.675	22.567	.31						

* Sap-wood.

† Partially sap-wood.

‡ Percentage of resin in heart-wood where both heart-wood and sap-wood occur in the same culture block.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
Longleaf pine (*Pinus palustris*)											
B1504	31.9	22.070	.691	21.982	.40						
B1505	32.7	22.618	.692	22.567	.23						
B1506	31.3	21.668	.693	21.613	.25						
C1501	32.	23.877	.715	23.865	.05	.96	30.	11.	2.25	.717	.49
C1502	31.4	23.618	.720	23.470	.63						
C1503	31.1	23.491	.724	23.381	.47						
C1504	31.	23.310	.719	23.070	1.03						
C1505	31.8	23.774	.714	23.697	.32						
C1506	30.4	22.550	.709	22.452	.44						
D1501	34.	23.984	.705	23.875	.46	.88	30.	14.	2.25	.698	.37
D1502	35.	24.217	.692	24.129	.36						
D1503	34.	23.707	.697	23.612	.40						
D1504	34.	23.678	.697	23.609	.29						
D1505	34.9	24.447	.700	24.378	.28						
D1506	33.	23.011	.697	22.914	.42						
E1501	33.5	24.192	.722	23.490	2.91	.86	35.	17.	3.25	.724	2.68
E1502	33.	24.027	.727	23.406	2.58						
E1503	33.3	24.095	.724	23.480	2.55						
† F1501	34.2	24.660	.721	23.862	3.23	1.06	30.	15.	4.	.709	3.35
† F1502	34.9	25.570	.733	24.737	3.26						
† F1503	34.8	25.163	.723	24.166	3.96						
† F1504	34.1	24.227	.710	23.512	2.95						
† F1505	34.	23.332	.685	22.672	2.83						
† F1506	32.8	22.518	.685	21.640	3.90						
* G1501	33.8	22.846	.676	22.200	2.82	.96	32.	11.	5.	.685	3.30
* G1502	33.7	23.110	.685	22.498	2.65						
* G1503	32.7	22.492	.687	22.113	1.69						
* G1504	32.3	22.362	.691	20.991	6.13						
* G1505	31.2	21.520	.689	20.825	3.23						
* G1506	31.5	21.725	.689	21.006	3.31						
A1601	32.	24.225	.757	22.970	5.18	2.7	40.	23.	1.25	.746	4.38
A1602	32.2	24.478	.761	23.540	3.83						
A1603	32.	23.927	.747	22.480	6.04						
A1604	32.	23.431	.732	22.850	2.48						
B1601	30.8	22.798	.740	20.480	10.18	2.44	40.	20.	1.75	.726	8.57
B1602	31.	22.404	.722	20.490	8.54						
B1603	30.7	22.002	.716	20.450	7.05						
C1601	30.	22.000	.733	19.710	10.41	5.44	38.	17.	2.75	.740	10.11
C1602	30.7	22.717	.740	20.600	9.31						
C1604	30.6	22.869	.747	20.440	10.61						
D1601	30.2	23.052	.763	22.250	3.48	3.4	40.	17.	3.75	.768	3.10
D1602	30.3	23.431	.773	22.795	2.71						
† E1601	32.	22.439	.701	22.057	1.70	2.04	35.	16.	4.75	.696	8.68
† E1602	30.	20.692	.690	17.480	15.5						
† E1603	30.5	21.245	.696	21.239	.03						

* Sap-wood.
† Partially sap-wood.

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Longleaf pine (*Pinus palustris*)											
† E1604	30.	20.971	.699	17.310	17.5						
* F1601	30.9	20.386	.658	19.570	4.01	3.20	40.	10.	5.75	.664	8.19
* F1602	29.5	19.445	.658	16.990	12.62						
* F1603	29.7	19.949	.671	19.270	3.41						
* F1604	30.	20.055	.668	17.500	12.75						
* G1601	31.2	21.288	.682	17.740	16.65	2.58	37.	12.	6.75	.681	12.56
* G1602	31.	20.970	.676	17.605	16.05						
* G1603	30.4	20.720	.681	20.691	.14						
* G1604	29.5	20.280	.687	16.741	17.4						
* H1601	32.5	21.834	.671	20.275	7.14	2.14	39.	8.5	7.75	.670	6.74
* H1602	31.8	21.292	.670	19.940	6.34						
* I 1601	30.9	22.364	.723	18.460	17.45	1.84	36.	10.	8.75	.721	17.09
* I 1602	31.	22.165	.715	17.855	19.45						
* I 1603	30.2	21.879	.724	18.270	16.45						
* I 1604	29.7	21.480	.724	18.250	15.01						
A1701	32.	23.846	.745	22.719	4.72	32.48	25.	10.	.5	.733	5.87
A1702	31.6	22.075	.699	21.156	4.16						
A1703	30.	21.282	.709	20.061	5.73						
A1704	28.	20.557	.734	19.272	6.25						
A1705	26.	20.252	.778	18.532	8.49						
B1701	31.	22.809	.735	20.738	9.08	23.8	25.	10.	.5	.717	8.06
B1702	30.7	21.684	.706	20.142	7.11						
B1703	32.3	22.067	.683	20.568	6.79						
B1704	31.	22.257	.717	20.710	6.95						
B1705	32.	23.851	.745	21.370	10.40						
C1703	30.2	18.847	.624	18.360	2.58	13.94	25.	8.	1.5	.629	2.68
C1704	28.3	17.566	.620	17.100	2.65						
C1705	28.9	18.337	.634	17.820	2.82						
D1701	32.	20.694	.646	19.440	6.06	15.0	25.	9.	1.5	.643	8.33
D1702	31.5	19.996	.634	18.992	5.02						
D1703	32.5	20.891	.643	19.370	7.28						
D1704	30.8	19.481	.633	16.449	15.56						
D1705	31.7	20.963	.661	19.342	7.74						
E1701	31.6	22.239	.703	21.206	4.64	10.46	28.	14.	2.5	.683	4.56
E1702	32.3	22.076	.684	21.050	4.65						
E1703	31.5	21.488	.683	20.691	3.71						
E1704	31.9	21.510	.674	20.379	5.26						
E1705	31.9	21.518	.674	20.540	4.55						
F1701	32.	19.850	.620	19.128	3.64	10.6	29.	12.	2.5	.629	3.41
F1702	32.1	19.908	.620	19.110	4.01						
F1703	31.7	19.440	.613	19.438	.01						
F1704	32.3	20.683	.640	19.776	4.39						
F1705	32.	20.971	.655	19.923	5.00						
G1701	31.8	20.292	.638	19.573	3.54	4.7	28.	13.	3.5	.617	3.23
G1702	31.6	19.995	.632	19.225	3.85						
G1703	31.	19.117	.616	18.528	3.08						
G1704	30.8	18.587	.603	18.010	3.11						
G1705	30.	17.905	.597	17.443	2.58						
H1701	32.3	24.521	.759	22.716	7.36	13.2	30.	18.	3.5	.726	7.00
H1702	32.	23.870	.746	21.913	8.19						
H1703	32.	23.138	.722	21.451	7.29						
H1704	32.7	22.986	.703	21.561	6.2						
H1705	31.2	21.923	.703	20.611	5.99						
A1801	31.	19.791	.638	19.100	3.49	2.7	20.	12.	.75	.599	2.15

* Sap-wood.
† Partially sap-wood.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
				Longleaf pine (*Pinus palustris*)							
A1802	31.8	19.095	.600	18.520	3.01						
A1803	32.	19.476	.608	18.910	2.9						
A1804	30.9	18.943	.613	18.650	1.55						
A1805	31.2	17.795	.570	17.686	.61						
A1806	31.	17.523	.565	17.291	1.32						
B1801	30.	18.092	.603	18.070	.12	5.9	20.	13.	.75	.621	1.21
B1802	28.7	17.594	.613	17.591	.02						
B1803	29.	19.345	.667	19.004	1.76						
B1804	28.9	18.547	.642	18.243	1.64						
B1805	29.6	17.809	.601	17.504	1.71						
B1806	30.5	18.312	.600	18.132	.98						
C1801	30.8	24.037	.780	23.004	4.30	3.9	25.	19.	1.5	.582	1.01
C1802	30.8	17.134	.556	17.015	.69						
C1803	31.4	17.172	.547	17.022	.87						
C1804	31.1	16.913	.543	16.913	.00						
C1805	31.2	16.742	.537	16.733	.05						
C1806	31.8	16.800	.528	16.782	.11						
D1801	31.	18.253	.588	18.010	1.33	3.96	25.	14.	1.5	.568	1.68
D1802	32.5	19.230	.591	18.757	2.46						
D1803	32.6	18.507	.567	18.126	2.06						
D1804	30.2	16.554	.548	16.451	.62						
D1805	29.	16.153	.557	15.978	1.08						
D1806	29.	16.200	.558	15.786	2.56						
E1801	30.6	16.229	.530	16.040	1.17	5.4	27.	18.	2.5	.527	.91
E1802	30.5	15.997	.524	15.940	.36						
E1803	30.1	15.783	.524	15.670	.72						
E1804	31.1	16.441	.529	16.212	1.39						
F1802	32.7	18.750	.574	18.010	3.95	3.	27.	26.	2.5	.536	2.26
F1803	31.	16.393	.528	16.215	1.09						
F1804	31.9	16.762	.525	16.500	1.57						
F1805	31.5	16.520	.524	16.170	2.12						
F1806	32.	16.994	.530	16.550	2.61						
**G1801	31.	31.403	1.013	28.107	10.49	5.56	27.	26.	3.5	.576	2.15
G1802	31.8	16.189	.508	16.102	.54						
G1803	30.7	14.460	.471	14.221	1.65						
G1804	31.5	15.226	.483	15.212	.09						
G1805	32.	15.542	.486	15.540	.01						
G1806	32.4	16.067	.496	16.052	.09						
H1801	32.4	16.985	.524	16.465	3.06	4.12	27.	23.	3.5	.523	3.38
H1802	34.7	18.515	.533	17.996	2.8						
H1803	32.	16.915	.528	16.271	3.81						
H1804	33.3	17.283	.519	16.711	3.31						
H1805	32.	16.625	.519	16.006	3.72						
H1806	32.2	16.726	.519	16.123	3.6						
I 1802	35.1	20.556	.585	20.214	1.67	4.14	28.	36.	4.5	.531	.90
I 1803	31.9	16.523	.517	16.491	.19						
I 1804	32.	16.713	.522	16.642	.43						

** Knot.

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Longleaf pine (*Pinus palustris*)											
I 1805	31.	16.052	.518	15.890	1.01						
I 1806	31.8	16.368	.515	16.173	1.19						
A1901	32.5	20.185	.620	19.286	4.46	2.7	30.	17.	.5	.636	3.10
A1902	31.4	19.275	.614	18.711	2.93						
A1903	32.	20.354	.636	19.791	2.77						
A1904	32.1	21.326	.663	20.735	2.78						
A1905	30.	19.441	.648	18.944	2.56						
B1901	30.	20.005	.667	18.432	7.87	3.16	32.	12.	.5	.668	4.29
B1902	31.5	20.733	.657	20.035	3.37						
B1903	31.	22.092	.712	21.506	2.65						
B1904	30.8	20.277	.658	19.805	2.32						
B1905	30.5	19.736	.647	18.694	5.28						
C1901	32.5	22.598	.695	21.780	3.62	3.22	40.	12.	1.5	.701	3.24
C1902	31.5	21.881	.695	21.000	4.03						
C1903	30.7	22.732	.740	21.950	3.44						
C1904	30.	20.654	.688	20.130	2.53						
C1905	30.3	20.784	.686	20.250	2.57						
D1901	32.7	22.412	.685	21.861	2.46	4.24	40.	10.	2.5	.684	2.33
D1902	31.9	22.249	.697	21.754	2.32						
D1903	32.5	22.814	.702	22.272	2.37						
D1904	32.	21.634	.675	21.135	2.30						
D1905	31.5	20.913	.664	20.449	2.22						
E1901	31.	21.130	.681	20.770	1.70	8.86	42.	9.	3.5	.705	2.08
E1903	31.2	22.398	.717	21.948	2.01						
E1904	31.5	22.637	.718	22.063	2.54						
F1901	33.3	23.500	.706	21.433	8.80	6.3	35.	12.	4.5	.713	8.83
F1902	32.7	23.200	.709	21.091	9.09						
F1903	32.	22.977	.718	20.825	9.38						
F1904	32.	22.884	.715	20.890	8.71						
F1905	31.	22.318	.720	20.496	8.16						
G1901	31.5	21.116	.670	21.054	.29	16.26	37.	13.	5.5	.684	1.86
G1902	33.7	22.769	.675	22.540	1.01						
G1903	32.9	22.054	.670	22.037	.08						
G1904	33.4	23.037	.689	22.319	3.11						
G1905	32.	22.936	.716	21.831	4.82						
H1901	33.8	22.130	.654	21.384	3.37	25.68	36.	12.	6.5	.742	9.06
H1904	34.8	26.802	.770	24.063	10.21						
H1905	34.	27.271	.803	23.565	13.59						
Loblolly pine (*Pinus Taeda*)											
B2001	31.	15.685	.506	14.522	7.42	30.6	14.	2.0	2.25	.500	15.44
B2002	29.5	14.438	.490	13.515	6.39						
B2003	29.8	14.630	.491	13.535	7.48						
B2004	31.	15.601	.503	11.450	26.6						
B2005	31.2	15.879	.508	11.226	29.3						
C2001	30.	15.778	.526	15.406	2.36	6.0	13.	1.5	3.	.519	1.47
C2002	28.	15.140	.541	14.927	1.41						
C2003	28.7	14.847	.517	14.820	.18						
C2004	29.5	14.980	.507	14.852	.86						
C2005	28.	14.156	.505	13.794	2.56						
D2001	30.	15.720	.527	15.117	3.84	4.96	17.	2.	2.75	.518	4.00
D2002	29.7	15.404	.518	14.820	3.79						
D2004	32.	16.183	.505	15.475	4.38						
E2001	31.3	18.350	.586	12.258	33.20	2.9	14.	1.5	2.25	.504	23.17
E2002	31.	16.669	.538	13.263	20.42						
E2003	31.	14.575	.470	11.630	20.22						

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
Loblolly pine (*Pinus Taeda*)											
E2004	30.7	14.376	.468	10.932	23.99						
E2005	28.	12.830	.458	10.521	18.00						
F2001	31.4	15.120	.481	12.201	19.30	6.08	12.	1.5	2.75	.472	21.67
F2004	31.3	14.655	.468	10.883	25.72						
F2005	29.	13.520	.466	9.818	19.98						
G2001	29.5	13.803	.468	11.500	16.70	4.46	13.	1.5	3.5	.479	9.27
G2002	28.5	13.680	.480	12.831	6.21						
G2003	29.	14.026	.483	13.102	6.59						
G2004	29.	14.033	.484	13.452	4.14						
G2005	26.	12.488	.480	10.900	12.71						
†H2001	31.	15.644	.504	15.005	4.08	3.02	16.	2.	4.25	.494	4.15
†H2002	29.9	14.800	.495	14.213	3.97						
†H2003	30.	14.830	.494	14.290	3.64						
†H2004	30.8	15.040	.488	14.327	4.74						
†H2005	28.	13.723	.490	13.128	4.33						
B2101	27.	11.142	.412	9.030	18.93	3.24	17.	3.	1.0	.411	13.12
B2102	27.	11.262	.417	9.632	14.49						
B2103	27.3	11.128	.407	9.776	12.16						
B2104	27.	11.195	.415	10.112	9.68						
B2105	26.6	10.800	.406	9.633	10.34						
C2101	27.	10.737	.397	9.541	11.12	4.72	17.	3.	1.	.411	7.58
C2102	27.5	11.103	.403	10.215	8.01						
C2104	28.	12.117	.432	11.680	3.61						
D2101	26.8	10.890	.407	10.206	6.29	4.16	16.	2.5	1.5	.406	4.44
D2102	27.	11.101	.411	10.617	4.36						
D2105	27.8	11.137	.401	10.840	2.67						
E2101	28.7	11.478	.400	10.871	5.28	4.46	14.	3.	2.	.421	6.62
E2102	28.4	11.983	.422	11.237	6.24						
E2103	28.	12.115	.432	11.233	7.27						
E2104	27.8	12.030	.433	11.193	6.96						
E2105	26.7	11.193	.419	10.374	7.33						
F2101	29.	12.187	.419	11.765	3.47	2.48	15.	2.5	2.25	.432	2.88
F2102	29.	12.570	.433	12.427	1.14						
F2103	28.	12.527	.447	11.952	4.59						
F2104	27.9	12.543	.449	12.086	3.64						
F2105	26.4	10.909	.413	10.741	1.54						
G2101	30.	13.586	.453	12.760	6.09	3.84	16.	3.25	3.	.437	7.90
G2102	29.	12.250	.422	11.077	9.59						
G2103	28.8	12.390	.429	11.350	8.40						
G2104	30.	12.790	.426	11.703	8.50						
G2105	28.	12.340	.441	11.485	6.93						
H2101	30.	12.601	.420	11.580	8.11	4.20	16.	3.	3.	.426	7.09
H2102	28.2	11.976	.424	11.300	5.65						
H2103	28.	11.865	.424	11.090	6.54						
H2104	29.	12.255	.422	11.300	7.8						
H2105	27.	11.905	.441	11.030	7.35						

† Partially sap-wood.

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Loblolly pine (*Pinus Taeda*)											
* B2201	26.5	12.598	.475	10.566	16.14	2.28	28.	2.5	4.5	.471	13.84
* B2202	28.7	13.677	.476	11.594	15.24						
* B2203	28.	13.250	.473	11.525	13.02						
* B2204	28.	12.925	.462	11.379	11.96						
* B2205	28.	13.166	.470	11.478	12.82						
* C2201	26.	12.629	.485	12.059	4.51	2.28	28.	2.5	5.	.476	15.93
* C2202	29.2	13.860	.475	11.931	13.91						
* C2203	28.5	13.560	.476	11.073	18.35						
* C2204	27.5	12.874	.468	8.693	32.50						
* C2205	27.	12.904	.478	11.567	10.37						
* D2202	29.8	13.686	.459	8.647	36.85	3.32	24.	3.	5.75	.462	40.75
* D2203	28.4	13.194	.464	7.023	46.80						
* D2205	28.	13.294	.474	8.156	38.60						
* E2201	25.	12.432	.497	11.806	5.04	2.8	26.	3.	5.5	.486	4.73
* E2202	27.5	13.409	.487	12.904	3.77						
* E2203	26.	12.764	.491	12.350	3.24						
* E2204	26.	12.310	.474	11.651	5.35						
* E2205	26.2	12.690	.484	11.895	6.26						
* F2201	26.5	13.672	.516	9.384	31.40	3.1	26.	4.	6.25	.508	38.3
* F2202	28.	14.115	.504	8.330	40.9						
* F2203	27.	13.623	.504	7.103	47.9						
* F2204	28.	14.169	.506	8.840	37.6						
* F2205	28.	14.250	.509	9.426	33.9						
* G2201	28.	14.466	.517	9.206	36.4	2.38	32.	5.	6.75	.513	10.48
* G2202	28.	14.360	.513	13.869	3.42						
* G2203	27.5	14.281	.519	13.811	3.29						
* G2204	26.2	13.510	.516	12.906	4.47						
* G2205	26.	12.985	.499	12.358	4.84						
* H2201	28.2	16.306	.578	10.781	33.9	2.8	32.	6.5	7.	.558	27.47
* H2202	28.3	16.004	.566	10.687	33.22						
* H2203	27.9	15.405	.552	11.750	23.75						
* H2204	27.5	15.022	.546	11.174	25.60						
* H2205	26.8	14.697	.548	11.629	20.90						
† B2301	30.7	15.465	.504	14.644	5.31	3.28	15.	2.75	2.75	.503	4.97
† B2302	30.	15.046	.502	14.286	5.05						
† B2303	30.	15.534	.518	14.978	3.58						
† B2304	30.	15.545	.518	14.640	5.82						
† B2305	29.7	14.013	.472	13.296	5.12						
C2301	31.5	17.449	.554	16.461	5.66	6.7	15.	1.5	2.75	.549	5.03
C2302	30.	16.705	.556	15.760	5.66						
C2303	30.	17.373	.579	16.446	5.33						
C2304	30.	16.980	.566	15.996	5.97						
C2305	29.	14.239	.491	13.875	2.56						
† D2302	29.7	13.145	.442	9.598	27.	2.36	15.	2.	3.5	.450	29.40
† D2304	28.	13.016	.465	7.935	39.02						
† D2305	27.4	12.126	.443	9.436	22.20						
* E2303	27.5	13.909	.506	10.885	21.75	.92	25.	3.	4.25	.494	32.41
* E2304	27.	13.767	.510	7.700	44.1						
* E2305	26.	12.086	.465	8.294	31.4						
* F2301	27.5	12.383	.450	10.785	12.91	3.22	25.	3.	3.75	.481	17.99
* F2302	27.	12.245	.454	10.744	12.26						
* F2303	26.9	13.717	.510	11.890	13.3						
* F2304	26.5	13.550	.511	12.033	11.2						
* F2305	26.3	12.690	.482	7.586	40.3						

* Sap-wood.

† Partially sap-wood.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I Culture block	II Volume (cc.)	III Weight before decay (gm.)	IV Specific gravity	V Weight after decay (gm.)	VI Per cent loss in weight due to decay	VII Per cent resin	VIII Per cent summer wood	IX Number growth rings per inch	X Inches from pith	XI Average specific gravity	XII Average per cent loss in weight
					Loblolly pine (*Pinus Taeda*)						
*G2302	26.2	14.456	.552	12.777	11.61	2.38	30.	3.5	4.5	.534	11.40
*G2304	27.8	14.556	.523	12.685	12.87						
*G2305	25.4	13.395	.527	12.094	9.72						
*E2402	26.	12.095	.465	10.111	16.42	2.92	24.	2.75	3.75	.458	25.64
*E2403	26.6	12.300	.463	9.930	19.28						
*E2404	26.4	12.087	.458	8.257	31.75						
*E2405	25.2	11.401	.453	7.398	35.10						
*G2401	26.	12.711	.489	8.721	31.4	4.4	27.	5.5	4.5	.479	30.16
*G2402	26.3	12.630	.480	8.502	32.63						
*G2403	26.5	12.814	.484	9.637	24.8						
*G2404	26.5	12.575	.475	8.380	33.4						
*G2405	26.	12.159	.467	8.722	28.25						
*H2401	26.	14.490	.556	10.824	25.31	3.12	29.	7.5	5.	.530	23.64
*H2404	24.4	12.670	.519	9.810	22.6						
*H2405	24.4	12.615	.517	9.715	23.						
*C2501	28.	13.547	.484	8.470	37.5	2.8	20.	2.25	4.	.478	25.35
*C2502	26.7	12.740	.477	8.110	36.3						
*C2503	27.	12.749	.472	6.915	45.7						
*C2504	27.9	13.267	.476	12.838	3.23						
*C2505	27.8	13.365	.480	12.828	4.02						
*D2501	26.8	12.770	.476	11.068	13.34	3.18	20.	2.5	4.	.469	19.07
*D2502	26.	12.278	.472	9.480	22.8						
*D2503	25.9	11.973	.462	9.511	20.59						
*D2504	25.9	11.966	.462	9.531	20.37						
*D2505	25.	11.838	.473	9.678	18.25						
*E2501	26.5	12.687	.478	12.400	2.26	3.	25.	2.5	3.5	.461	8.18
*E2502	26.	12.158	.467	11.571	4.84						
*E2503	26.	11.975	.460	11.376	5.01						
*E2505	25.	10.956	.438	8.700	20.6						
*F2501	27.	12.915	.478	10.542	18.37	2.14	23.	2.75	4.25	.468	31.63
*F2502	25.5	12.144	.476	10.907	10.18						
*F2503	25.	11.489	.459	6.438	44.1						
*F2504	25.2	11.784	.467	7.545	36.						
*F2505	24.1	11.134	.462	5.627	49.5						
*H2501	27.	13.557	.502	4.377	67.71	3.26	27.	3.5	4.75	.486	54.82
*H2502	27.	13.305	.493	4.650	65.1						
*H2503	26.3	12.680	.482	6.782	46.5						
*H2504	27.	12.950	.480	5.570	57.						
*H2505	26.	12.388	.476	7.710	37.8						
*B2601	26.5	13.747	.519	10.541	23.33	3.4	35.	7.	5.	.536	23.68
*B2604	27.	14.616	.542	11.073	24.17						
*B2605	26.	14.375	.553	10.990	23.55						
*C2601	27.3	14.103	.517	10.045	28.78	4.5	35.	7.	5.	.520	20.34
*C2602	28.	14.536	.519	11.242	22.65						
*C2603	27.8	14.559	.523	10.796	25.85						
*C2604	28.4	14.680	.517	11.343	22.79						

* Sap-wood.

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Loblolly pine (*Pinus Taeda*)											
* C2605	27.9	14.650	.525	14.410	1.64						
* D2601	28.	14.590	.521	9.357	35.9	2.3	35.	7.	5.5	.532	35.02
* D2602	27.	14.427	.534	10.507	27.2						
* D2603	26.8	14.353	.535	9.323	35.04						
* D2604	27.	14.393	.532	8.463	41.2						
* D2605	26.	14.044	.540	9.024	35.78						
* E2601	27.2	14.263	.524	13.594	4.69	2.14	38.	6.	6.	.516	12.27
* E2602	25.8	13.103	.507	12.775	2.50						
* E2603	24.6	12.944	.526	10.994	15.07						
* E2604	24.7	12.615	.510	9.834	22.04						
* E2605	24.	12.273	.512	10.180	17.06						
* F2601	27.5	15.016	.546	10.156	32.36	2.12	40.	6.	6.	.533	22.02
* F2603	27.	14.258	.528	10.538	26.10						
* F2605	26.	13.695	.526	12.655	7.6						
* G2601	27.	14.630	.542	13.495	7.75	2.04	40.	6.	6.	.532	7.68
* G2602	30.	16.350	.545	15.234	6.83						
* G2603	30.	15.905	.530	14.757	7.21						
* G2604	28.	14.613	.522	13.333	8.75						
* G2605	27.5	14.286	.519	13.163	7.87						
* H2601	27.5	14.424	.525	5.394	62.6	2.92	40.	6.	6.5	.509	30.46
* H2602	30.8	15.928	.517	9.672	39.3						
* H2603	30.	15.194	.506	13.425	11.64						
* H2604	28.7	14.303	.498	12.592	11.96						
* H2605	27.9	13.920	.499	10.196	26.78						
† B2701	30.	13.613	.454	11.097	18.47	1.56	20.	3.5	3.25	.476	14.79
† B2703	30.	15.220	.507	13.240	13.00						
† B2704	28.5	13.320	.467	11.600	12.91						
† C2701	30.	13.650	.455	12.365	9.41	1.5	20.	3.75	3.25	.461	19.05
† C2702	29.8	13.406	.450	9.894	26.2						
† C2705	29.5	14.144	.479	11.098	21.55						
* D2703	28.7	14.277	.497	12.931	9.42	1.24	23.	6.	4.	.504	8.86
* D2704	28.	13.855	.495	12.780	7.76						
* D2705	27.5	14.332	.521	12.987	9.39						
* E2701	27.9	14.450	.518	11.901	17.64	1.24	29.	10.5	4.75	.538	14.31
* E2702	27.	14.153	.524	11.485	18.85						
* E2703	28.	15.843	.566	13.882	12.38						
* E2704	27.4	14.833	.542	13.202	11.00						
* E2705	27.	14.638	.542	12.931	11.67						
* F2703	29.	15.087	.520	13.074	13.35	.94	28.	9.	4.25	.513	8.88
* F2704	27.8	14.185	.510	13.046	8.04						
* F2705	27.5	14.003	.509	13.270	5.24						
* G2701	28.5	15.194	.532	14.623	3.76	1.84	30.	14.	5.5	.539	4.39
* G2702	26.4	13.962	.529	13.321	4.59						
* G2705	26.8	14.915	.556	14.194	4.83						
* H2701	28.7	15.730	.549	11.032	29.85	2.48	30.	13.	5.25	.563	19.50
* H2702	27.	14.996	.555	12.759	14.92						
* H2703	26.	14.775	.568	12.115	18.						
* H2704	26.	14.617	.562	11.722	19.8						
* H2705	25.	14.515	.581	12.350	14.91						
* B2801	28.	13.812	.493	9.548	30.8	3.1	25.	2.	3.	.480	34.20
* B2802	27.5	13.515	.491	10.354	23.4						
* B2803	28.3	14.010	.495	8.560	38.9						
* B2804	27.5	12.635	.459	7.037	44.3						
* B2805	27.	12.539	.464	8.324	33.6						

* Sap-wood.
† Partially sap-wood.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
				Loblolly pine (*Pinus Taeda*)							
* C2801	27.5	12.985	.471	9.116	29.82	2.36	25.	2.5	3.5	.481	37.61
* C2802	27.	12.926	.478	7.351	43.10						
* C2805	27.	13.369	.495	8.041	39.9						
* D2801	27.	13.173	.487	9.364	28.91	2.22	25.	2.5	3.75	.487	17.35
* D2802	27.	13.136	.486	9.905	24.6						
* D2803	25.	11.947	.478	10.665	10.72						
* D2804	26.	12.973	.499	11.363	12.41						
* D2805	26.8	12.997	.484	11.685	10.10						
* E2801	27.	13.385	.495	12.063	9.90	2.16	27.	2.75	3.75	.502	10.16
* E2802	26.	13.285	.510	11.774	11.39						
* E2803	26.8	13.396	.500	12.164	9.19						
* F2801	27.	13.657	.505	9.381	31.3	2.64	27.	3.	4.5	.494	19.59
* F2802	27.	13.375	.495	10.540	21.2						
* F2803	24.5	11.975	.489	10.590	11.58						
* F2804	27.	13.210	.489	11.003	16.70						
* F2805	26.5	13.012	.491	10.780	17.15						
* G2801	26.8	12.742	.476	11.995	5.86	1.96	27.	3.5	4.5	.480	19.69
* G2802	26.8	12.954	.483	12.122	6.42						
* G2803	27.	14.047	.520	9.177	34.7						
* G2804	26.6	12.660	.476	9.030	38.65						
* G2805	26.	11.622	.447	10.131	12.82						
* H2801	28.	14.021	.501	6.855	51.10	2.06	28.	6.	5.	.493	43.72
* H2804	26.	12.703	.489	6.980	45.10						
* H2805	25.	12.267	.490	7.982	34.95						
* B2905	26.8	12.809	.478	12.180	4.91	1.54	35.	6.25	3.25	.478	4.91
* C2902	25.5	13.288	.521	12.714	4.32	1.92	35.	6.5	3.5	.515	4.27
* C2903	25.5	12.973	.508	12.524	3.46						
* C2905	26.4	13.607	.515	12.924	5.02						
* D2901	28.1	14.340	.510	13.641	4.87	1.12	35.	13.5	4.	.497	8.99
* D2902	29.5	14.551	.493	13.612	6.45						
* D2903	28.5	14.103	.495	11.739	16.76						
* D2904	29.8	14.722	.494	12.982	11.81						
* D2905	28.	13.763	.492	13.066	5.06						
* E2901	26.8	14.070	.525	11.068	21.36	.9	35.	11.	4.25	.520	24.04
* E2902	27.	13.901	.515	10.780	22.45						
* E2903	26.	13.477	.518	9.386	30.39						
* E2904	26.	13.521	.520	9.852	27.16						
* E2905	25.7	13.360	.520	10.842	18.84						
* F2902	25.3	14.189	.560	13.200	6.97	.66	35.	10.	4.5	.562	3.46
* F2904	24.4	13.869	.568	13.516	2.55						
* F2905	24.6	13.710	.557	13.592	.86						
* G2901	26.	15.537	.597	14.661	5.64	.72	32.	7.5	4.25	.579	4.21
* G2902	26.	15.143	.582	14.220	6.09						
* G2903	25.	14.277	.571	13.784	3.45						
* G2904	25.	14.450	.578	13.970	3.32						
* G2905	25.	14.157	.566	13.795	2.56						

* Sap-wood.

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Loblolly pine (*Pinus Taeda*)											
*H2901	25.	13.835	.554	13.098	5.33	.82	35.	12.5	5.	.570	5.90
*H2902	24.	13.643	.569	12.887	5.54						
*H2903	24.	13.675	.570	12.835	6.15						
*H2904	24.	13.844	.577	13.104	5.34						
*H2905	22.5	13.038	.580	12.105	7.16						
† B3001	30.	13.835	.461	13.200	4.59	1.08	22.	3.5	3.5	.456	8.93
† B3002	29.8	13.297	.446	12.750	4.12						
† B3003	29.8	13.384	.449	12.821	4.21						
† B3004	29.8	13.625	.457	11.648	14.5						
† B3005	28.6	13.400	.468	11.092	17.23						
† C3001	30.	13.430	.447	10.818	19.42	1.76	22.	3.5	3.5	.451	12.05
† C3002	30.	13.395	.446	11.937	10.88						
† C3003	31.5	14.128	.448	12.793	9.45						
† C3004	32.5	14.605	.449	13.749	5.86						
† C3005	32.	14.860	.464	12.686	14.62						
†D3001	30.	13.038	.434	10.212	21.70	2.76	25.	4.	4.25	.441	11.47
†D3004	30.	12.925	.431	11.959	7.47						
†D3005	29.5	13.555	.459	12.845	5.24						
* E3001	29.	14.045	.484	13.368	4.82	2.4	27.	10.	5.	.489	4.40
* E3002	27.	13.330	.494	12.800	3.97						
* F3001	29.3	13.493	.460	10.775	20.15	1.84	26.	7.	4.5	.471	27.66
* F3002	30.5	13.940	.457	10.511	24.56						
* F3003	30.4	14.005	.461	10.423	25.57						
* F3004	29.5	14.186	.480	10.711	24.51						
* F3005	28.	13.909	.497	7.856	43.51						
*G3001	30.	15.523	.517	9.399	39.44	2.5	29.	10.5	5.25	.512	37.0
*G3003	30.	15.357	.512	9.941	35.26						
*G3004	29.9	15.193	.507	9.681	36.30						
*H3001	27.8	14.414	.518	12.454	13.60	1.84	30.	16.	5.75	.522	17.01
*H3002	28.	14.705	.525	12.640	14.04						
*H3003	26.8	13.930	.520	11.137	20.03						
*H3004	27.	13.876	.514	10.856	21.80						
*H3005	26.	13.864	.533	11.701	15.60						
Longleaf pine (*Pinus palustris*)											
F3101	27.4	17.293	.630	17.280	.08	3.44	45.	26.	4.75	.641	1.01
F3102	27.3	17.644	.646	17.642	.01						
F3103	28.	18.427	.658	18.424	.02						
F3104	26.4	17.030	.645	16.722	1.81						
F3105	25.7	16.058	.625	15.552	3.15						
G3101	30.	18.890	.629	18.879	.06	4.26	45.	35.	4.5	.645	.03
G3102	29.8	18.299	.614	18.292	.04						
G3103	27.5	19.820	.721	19.814	.03						
G3104	29.	18.270	.630	18.268	.01						
G3105	26.8	16.980	.634	16.977	.02						
I 3101	29.8	19.350	.649	19.346	.02	6.02	45.	24.	5.5	.649	.11
I 3102	30.	19.550	.651	19.502	.25						
I 3103	30.4	19.916	.655	19.880	.18						
I 3104	29.8	19.050	.639	19.037	.07						
I 3105	28.	18.306	.653	18.298	.04						
J 3103	29.2	20.756	.711	20.755	.004	10.28	45.	24.	5.5	.709	.23
J 3104	29.4	20.746	.706	20.690	.27						
J 3105	28.	19.827	.711	19.757	.35						
K3101	29.5	19.864	.674	19.860	.02	15.7	45.	25.	5.75	.680	.88

* Sap-wood.

† Partially sap-wood.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
Longleaf pine (*Pinus palustris*)											
K3102	28.7	19.737	.688	19.735	.01						
K3103	27.9	19.267	.691	18.970	1.54						
K3104	27.8	18.798	.675	18.640	.84						
K3105	27.8	18.749	.674	18.372	2.01						
M3101	30.3	22.250	.734	20.235	9.05	18.4	48.	25.	6.5	.726	9.09
M3102	30.	22.372	.746	20.072	10.3						
M3103	31.3	22.802	.728	20.780	8.87						
M3104	30.8	21.827	.708	19.903	8.81						
M3105	29.	20.764	.716	19.011	8.45						
N3101	29.	22.083	.761	20.100	8.98	22.26	48.	24.	6.5	.797	13.20
N3102	30.3	24.323	.802	21.670	10.91						
N3103	32.4	26.543	.819	22.441	15.46						
N3104	30.8	24.906	.809	21.129	15.16						
N3105	28.8	22.926	.796	19.368	15.51						
A3201	29.9	17.684	.591	17.684	.00	3.78	40.	6.5	2.	.605	1.04
A3202	30.	17.873	.596	17.872	.01						
A3203	29.	17.515	.604	16.606	5.19						
A3204	29.	17.903	.617	17.902	.01						
A3205	27.	16.618	.616	16.618	.00						
D3201	25.	15.476	.619	15.181	1.91	5.7	40.	10.	3.	.616	.67
D3202	28.7	17.530	.611	17.290	1.37						
D3203	27.	16.505	.611	16.500	.03						
D3204	27.	16.940	.627	16.937	.02						
D3205	27.8	17.068	.614	17.064	.02						
E3201	27.5	17.029	.619	17.019	.06	4.1	40.	9.	3.	.613	.06
E3202	30.3	18.857	.622	18.842	.08						
E3203	29.8	17.896	.600	17.892	.02						
E3204	30.5	18.799	.616	18.787	.06						
E3205	28.5	17.369	.610	17.352	.10						
F3201	25.8	16.508	.640	15.794	4.33	16.7	38.	10.	3.5	.676	7.62
F3202	30.	19.858	.662	18.557	6.55						
F3203	27.	19.175	.710	17.565	8.4						
F3204	27.5	18.841	.685	17.152	8.96						
F3205	28.	19.163	.684	17.272	9.87						
J 3203	28.	16.655	.595	14.593	12.4	4.2	36.	10.	4.	.600	8.11
J 3204	28.	16.930	.604	15.839	6.45						
J 3205	27.	16.276	.602	15.383	5.49						
K3201	26.	14.925	.574	14.454	3.16	9.72	35.	9.	4.5	.592	2.81
K3202	30.	17.190	.573	16.818	2.16						
K3203	27.4	15.723	.574	15.350	2.37						
K3204	27.6	16.666	.604	16.198	2.81						
K3205	28.5	18.179	.637	17.532	3.56						
L3201	28.	18.458	.659	17.980	2.59	22.52	35.	9.	5.	.725	4.80
L3202	30.	20.440	.681	19.745	2.42						
L3203	30.	21.297	.710	20.193	5.19						
L3204	31.5	24.330	.772	22.820	6.21						
L3205	29.5	23.791	.806	21.980	7.61						

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Longleaf pine (*Pinus palustris*)											
O3201	30.	24.556	.818	21.673	12.76	23.74	35.	10.5	5.5	.834	11.78
O3202	29.	24.151	.832	20.791	13.91						
O3203	27.5	22.610	.822	19.601	13.30						
O3204	28.	24.030	.859	21.652	9.89						
O3205	26.8	22.456	.838	20.417	9.07						
B3301	28.4	18.516	.652	18.516	.00	3.7	30.	12.	5.	.619	.004
B3302	28.	17.000	.607	17.000	.00						
B3303	30.4	18.610	.612	18.609	.01						
B3304	31.8	19.364	.608	19.362	.01						
D3301	26.3	16.579	.630	15.969	3.68	2.06	30.	18.	5.25	.605	3.12
D3302	25.3	15.957	.631	15.442	3.23						
D3303	26.7	16.280	.609	15.734	3.35						
D3304	27.5	16.434	.597	15.965	2.85						
D3305	27.	15.038	.557	14.665	2.48						
E3301	29.5	17.493	.592	15.421	11.85	15.56	25.	23.	5.75	.644	9.91
E3303	27.8	17.637	.634	16.596	5.91						
E3304	28.	18.720	.669	17.030	9.03						
E3305	27.6	18.775	.680	16.363	12.85						
I 3302	26.8	17.818	.665	17.792	.15	32.06	45.	14.	6.75	.773	5.22
I 3303	28.	20.116	.718	19.489	3.12						
I 3304	26.5	21.835	.824	20.526	5.98						
I 3305	27.	23.958	.887	21.433	10.55						
J 3301	27.7	16.610	.600	14.077	15.23	4.08	45.	14.	6.75	.593	3.08
J 3302	24.4	14.590	.597	14.587	.02						
J 3303	25.5	15.014	.589	15.000	.09						
J 3304	26.3	15.483	.589	15.479	.03						
J 3305	26.5	15.643	.590	15.638	.03						
L3301	27.	27.050	1.002	23.357	13.63	10.66	45.	12.5	7.	.901	13.18
L3302	25.	23.714	.949	20.202	14.81						
L3303	24.8	22.151	.894	18.822	15.03						
L3304	24.	20.916	.871	18.272	12.65						
L3305	23.	18.218	.792	16.434	9.79						
N3301	28.	15.893	.567	15.890	.02	2.62	45.	15.	7.5	.568	4.61
N3302	30.	17.250	.575	17.205	.26						
N3303	29.2	16.198	.554	16.198	.00						
N3304	28.3	16.190	.572	16.187	.02						
N3305	30.7	17.640	.575	13.627	22.78						
P3302	26.	26.006	1.000	22.112	14.98	20.58	45.	20.	8.00	.993	16.26
P3304	25.8	26.252	1.017	21.633	17.60						
P3305	24.	23.113	.963	19.365	16.21						
C3401	22.8	17.830	.619	17.350	2.69	5.58	32.	15.	2.5	.627	3.21
C3402	28.	17.525	.626	16.936	3.36						
C3403	28.	17.572	.627	16.914	3.75						
C3404	30.	18.843	.628	18.239	3.20						
C3405	31.	19.780	.638	19.170	3.08						
D3401	29.	18.446	.636	17.772	3.65	1.9	35.	18.	3.25	.633	4.18
D3402	28.	17.824	.636	17.010	4.56						
D3405	29.	18.500	.638	17.676	4.45						
H3401	28.	16.474	.588	16.271	1.23	2.0	40.	24.	4.	.592	8.84
H3402	27.	16.217	.601	16.102	.71						
H3403	27.	15.802	.586	15.756	.29						
H3404	26.4	15.540	.589	15.342	1.27						
H3405	25.2	15.017	.596	14.879	.92						
L3401	25.	14.814	.592	14.687	.86	1.86	40.	31.	4.5	.595	1.52
L3402	25.7	15.260	.594	15.042	1.43						
L3403	26.	15.467	.594	15.193	1.77						

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
Longleaf pine (*Pinus palustris*)											
L3404	26.	15.518	.597	15.241	1.79						
L3405	25.3	15.160	.599	14.896	1.74						
N3401	26.	15.030	.578	14.911	.79	3.22	35.	26.	5.25	.571	.83
N3402	25.8	14.584	.563	14.576	.05						
N3403	26.	14.926	.570	14.886	.27						
N3404	26.7	15.449	.567	15.323	.82						
N3405	26.	15.070	.579	14.737	2.21						
P3401	28.	15.274	.545	14.871	2.64	3.62	40.	27.	6.	.556	1.42
P3402	27.	14.887	.551	14.686	1.35						
P3403	28.	15.528	.519	15.373	1.00						
P3404	28.2	16.030	.569	16.030	.00						
P3405	28.8	17.179	.596	16.816	2.12						
E3501	26.8	17.096	.638	16.166	5.44	1.74	50.	42.	3.5	.645	2.84
E3502	25.7	16.519	.643	15.635	5.35						
E3503	25.5	16.265	.637	15.726	3.31						
E3504	26.	16.882	.649	16.863	.11						
E3505	25.	16.479	.659	16.478	.01						
G3501	26.	15.960	.614	15.566	2.47	2.94	50.	45.	4.	.610	.83
G3502	25.3	15.251	.602	15.250	.01						
G3505	24.5	15.065	.615	15.062	.02						
H3501	29.	18.383	.634	17.956	2.32	1.18	50.	38.	4.	.635	.77
H3504	28.7	18.292	.637	18.292	.00						
H3505	26.7	16.947	.635	16.947	.00						
K3502	27.	17.030	.631	17.030	.00	3.28	50.	38.	4.5	.633	1.54
K3503	27.	16.927	.627	16.481	2.63						
K3504	28.	17.960	.642	17.602	1.99						
M3501	27.5	19.235	.699	18.210	5.33	10.66	50.	37.	5.75	.689	3.04
M3502	28.	19.198	.685	18.522	3.52						
M3503	26.7	18.456	.691	17.939	2.80						
M3504	26.6	18.331	.689	18.021	1.69						
M3505	25.4	17.365	.684	17.042	1.86						
N3501	27.5	20.375	.740	19.893	2.37	11.04	50.	38.	5.5	.709	1.77
N3502	27.	20.110	.745	19.541	2.82						
N3503	26.	18.710	.720	18.412	1.59						
N3504	26.6	19.071	.617	18.988	.44						
N3505	26.	18.800	.722	18.490	1.65						
A3601	30.7	24.280	.791	21.479	11.53	29.48	27.5	19.	3.5	.786	10.7
A3602	30.3	24.455	.806	21.915	10.39						
A3603	30.7	24.100	.785	21.712	9.91						
A3604	31.	23.946	.772	21.225	11.39						
A3605	32.1	24.962	.777	22.400	10.28						
B3601	26.8	18.468	.689	17.638	4.5	14.72	40.	15.	4.	.696	2.91
B3602	26.8	18.566	.694	17.851	3.85						
B3603	28.	19.719	.704	19.200	2.63						
B3604	28.	19.665	.702	19.206	2.33						
B3605	28.4	19.704	.694	19.457	1.25						
C3601	26.3	21.420	.815	19.865	7.26	13.38	55.	13.	5.	.824	6.21

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Longleaf pine (*Pinus palustris*)											
C3602	26.5	22.230	.839	20.520	7.69						
C3603	27.	22.930	.849	21.411	6.62						
C3604	27.5	22.797	.829	21.538	5.54						
C3605	27.5	21.698	.789	20.837	3.97						
G3601	28.	20.250	.723	16.940	16.35	7.06	50.	13.	5.5	.709	15.79
G3602	26.5	18.866	.712	16.391	13.12						
G3605	26.3	18.230	.693	14.965	17.9						
† L3601	27.8	17.840	.642	16.475	7.64	7.4	37.5	16.	6.25	.630	13.23
† L3602	27.8	17.457	.628	15.305	12.32						
† L3603	28.7	17.868	.622	15.761	11.80						
† L3604	27.	16.886	.625	13.483	20.19						
† L3605	27.	17.170	.636	14.731	14.20						
†M3601	27.	17.856	.661	15.319	14.20	5.9	30.	17.	6.5	.664	21.10
†M3602	28.	18.507	.661	16.376	11.51						
†M3603	28.7	19.310	.672	13.649	29.30						
†M3604	28.5	19.159	.672	14.165	26.06						
†M3605	29.	19.080	.657	14.415	24.44						
*N3601	29.9	15.604	.522	12.610	19.19	10.7	31.	13.	7.	.538	26.62
*N3602	29.9	15.506	.519	11.651	24.82						
*N3603	30.2	16.057	.532	8.766	45.40						
*N3604	30.	16.370	.546	12.526	23.50						
*N3605	30.5	17.485	.573	13.960	20.2						
* P3601	30.	13.230	.441	9.215	30.35	7.02	20.	20.	7.75	.442	7.31
* P3602	30.	13.327	.444	12.991	2.52						
* P3603	30.	13.253	.441	13.039	1.62						
* P3604	30.8	13.607	.442	13.440	1.23						
* P3605	30.2	13.360	.442	13.248	.84						
B3701	29.8	17.610	.591	17.565	.26	23.64	25.	10.	1.5	.646	1.98
B3702	28.7	18.122	.631	17.945	.98						
B3703	29.	18.740	.646	18.512	1.22						
B3704	30.5	20.200	.662	19.830	1.83						
B3705	28.5	19.957	.700	19.290	3.34						
I 3701	27.8	16.138	.580	14.530	9.96	2.44	31.	12.	3.25	.607	12.58
I 3704	29.8	19.221	.645	17.188	10.58						
I 3705	30.	17.890	.596	14.809	17.22						
L3703	27.8	15.665	.564	14.996	4.26	2.78	30.	10.	4.	.565	5.37
L3704	28.6	16.210	.566	14.848	8.4						
L3705	26.	14.704	.566	14.195	3.46						
M3701	31.	18.390	.593	15.900	13.55	2.96	32.	9.	4.75	.593	13.86
M3702	31.3	18.576	.593	17.597	5.26						
M3703	29.	17.184	.592	15.330	10.8						
M3704	28.7	17.065	.595	12.116	29.						
M3705	27.	15.952	.591	14.246	10.7						
P3701	31.8	18.372	.577	18.372	.00	2.28	32.	9.	4.5	.574	8.41
P3702	31.	17.886	.576	17.886	.00						
P3703	28.	16.118	.575	15.236	5.47						
P3704	28.	16.207	.579	10.697	34.						
P3705	26.	14.696	.565	14.316	2.58						
A3801	29.	20.248	.698	20.244	.02	2.9	46.	8.5	2.5	.673	3.09
A3802	30.	20.037	.668	20.003	.17						
A3803	30.2	20.145	.667	20.132	.06						
A3804	32.	21.459	.671	19.554	8.87						
A3805	32.	21.093	.660	19.756	6.33						
B3801	30.	18.587	.619	17.994	3.19	3.02	45.	.9	3.5	.613	9.17

* Sap-wood.

† Partially sap-wood.

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Culture block	Volume (cc.)	Weight before decay (gm.)	Specific gravity	Weight after decay (gm.)	Per cent loss in weight due to decay	Per cent resin	Per cent summer wood	Number growth rings per inch	Inches from pith	Average specific gravity	Average per cent loss in weight
Longleaf pine (*Pinus palustris*)											
B3802	31.	19.006	.614	17.868	5.98						
B3803	30.5	18.366	.603	16.501	10.15						
B3804	33.2	20.227	.609	17.979	11.11						
B3805	32.	19.840	.620	16.776	15.45						
D3801	29.	19.544	.674	18.371	6.00	8.62	46.	9.	4.	.674	5.63
D3802	28.8	19.012	.660	17.833	6.19						
D3803	27.9	18.460	.662	17.477	5.33						
D3804	27.8	18.486	.665	17.392	5.93						
D3805	27.	19.230	.712	18.321	4.72						
F3801	28.	20.262	.724	19.016	6.14	3.38	47.	10.5	4.5	.658	4.92
F3802	30.5	19.981	.655	18.690	6.46						
F3803	29.	18.695	.644	17.969	3.89						
F3804	30.9	19.660	.636	18.882	3.96						
F3805	30.	19.007	.633	18.220	4.14						
H3801	28.	20.730	.740	18.932	8.67	15.5	47.	8.5	4.75	.704	7.94
H3802	28.	20.115	.718	18.292	9.06						
H3803	27.	18.803	.696	17.332	7.83						
H3804	26.8	18.317	.683	16.917	7.64						
H3805	28.	19.225	.686	17.974	6.51						
M3801	28.	22.965	.820	21.023	8.46	8.58	48.	9.5	5.5	.738	6.81
M3802	28.	21.016	.751	19.511	7.16						
M3803	26.	18.640	.717	17.392	6.69						
M3804	27.	19.245	.713	18.102	5.94						
M3805	26.	17.961	.691	16.921	5.79						
O3801	28.	28.248	1.010	23.045	18.40	23.98	50.	17.	6.25	.976	16.28
O3802	28.	28.182	1.010	23.221	17.62						
O3803	27.	27.052	1.002	21.930	18.94						
O3804	29.6	28.065	.948	23.044	17.89						
O3805	27.8	25.366	.911	23.200	8.56						
P3801	27.8	26.544	.955	22.770	14.22	22.6	52.	16.	7	.928	15.82
P3802	28.	26.683	.954	23.308	12.62						
P3803	28.4	26.650	.939	21.258	20.21						
P3804	29.4	26.914	.915	21.944	18.48						
P3805	29.5	25.845	.876	22.326	13.60						
A3901	27.7	17.330	.625	17.330	.00	20.08	28	10.	2.	.667	1.79
A3904	28.5	18.930	.664	18.570	1.9						
A3905	28.1	20.070	.714	19.372	3.48						
B3901	27.9	20.510	.735	19.661	4.14	36.18	30.	10.	2.75	.799	6.07
B3902	28.5	22.433	.787	21.051	6.16						
B3903	28.5	23.019	.808	21.836	5.14						
B3904	29.7	24.240	.816	22.491	7.21						
B3905	28.	23.847	.851	22.002	7.73						
E3901	27.4	26.679	.974	23.106	13.39	30.08	38.	20.	3.5	.903	12.15
E3903	28.	25.675	.917	22.180	13.6						
E3905	27	22.059	.817	19.971	9.46						
H3901	26.	27.032	1.039	23.431	13.31	37.02	50.	22.	4.25	1.063	12.21
H3902	26.8	28.330	1.057	24.552	13.33						

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Longleaf pine (*Pinus palustris*)											
H3903	28.	29.800	1.067	26.112	12.38						
H3904	27.7	29.724	1.076	26.683	10.23						
H3905	28.	30.216	1.079	26.646	11.80						
I 3901	28.	26.815	.958	22.723	15.25	26.86	51.	21.	4.25	.904	13.17
I 3902	26.7	25.195	.943	21.786	13.54						
I 3905	26.	21.134	.813	18.870	10.72						
K3901	27.	25.058	.928	22.974	8.32	10.44	50.	15.	4.75	.832	4.79
K3902	27.	23.628	.875	22.153	6.24						
K3903	26.	21.450	.825	20.630	3.82						
K3904	26.	20.386	.783	19.550	4.11						
K3905	26.	19.497	.750	19.213	1.46						
O3901	28.	28.175	1.006	25.150	10.75	19.74	52.	20.	5.75	.833	15.29
O3902	27.2	25.771	.946	20.276	21.35						
O3903	26.	21.048	.810	18.511	12.02						
O3904	26.	19.033	.732	16.373	13.99						
O3905	26.	17.623	.678	14.395	18.32						
P3901	29.8	27.638	.926	24.425	11.61	12.28	54.	16.	6.25	.690	18.03
P3902	29.	19.186	.661	14.775	23.01						
P3905	30.8	14.858	.482	11.097	19.46						
A4001	30.	18.060	.602	17.304	4.18	7.48	30.	10.	2.	.617	5.49
A4004	30.	18.672	.622	17.500	6.28						
A4005	28.5	17.827	.626	16.754	6.02						
F4002	27.	16.550	.613	16.546	.02	6.34	33.	25.	3.75	.616	.024
F4004	28.	17.287	.616	17.285	.01						
F4005	26.	16.093	.619	16.087	.04						
G4001	28.	16.583	.592	16.250	2.01	4.96	33.	29.	4.25	.599	5.52
G4002	27.	16.088	.596	15.850	1.48						
G4003	27.	16.108	.597	14.853	7.79						
G4004	27.4	16.769	.612	15.370	8.34						
G4005	26.2	15.707	.600	14.451	7.99						
I 4001	27.8	16.317	.586	14.542	10.88	8.38	36.	24.	4.75	.582	8.22
I 4002	26.7	15.659	.586	14.635	6.55						
I 4003	27.	15.734	.583	14.565	7.41						
I 4004	27.9	16.138	.578	14.071	12.81						
I 4005	27.5	15.814	.575	15.270	3.44						
N4001	27.5	17.892	.577	17.300	3.31	7.16	36.	30.	5.	.567	2.04
N4002	27.	17.333	.567	16.726	3.50						
N4003	26.9	16.440	.562	16.433	.04						
N4004	27.2	16.892	.565	16.795	.57						
N4005	26.	15.689	.564	15.255	2.77						
O4001	29.	16.884	.561	16.643	1.43	9.74	34.	30.	5.5	.561	1.88
O4002	28.	16.680	.560	16.050	3.78						
O4003	28.	15.830	.551	15.803	.17						
O4004	29.	17.625	.574	17.106	2.94						
O4005	28.	16.884	.560	16.705	1.06						
A4101	32.	15.940	.482	15.888	.33	22.76	6.	7.	0.00	.506	.83
A4102	31.	16.627	.504	16.361	1.60						
A4103	31.	16.148	.489	16.057	.56						
A4104	32.	17.638	.520	17.440	1.01						
A4105	29.7	16.300	.535	16.190	.68						
B4101	30.	17.715	.590	16.600	6.29	11.8	20.	9.	1.0	.596	4.74
B4102	30.	17.866	.595	17.845	.12						
B4103	29.8	17.500	.587	16.553	5.41						
B4104	31.5	19.092	.605	18.064	5.38						
B4105	30.	18.155	.605	16.976	6.49						
C4101	29.	17.780	.612	17.353	2.40	11.38	20.	9.	1.0	.615	2.44

TABLE I (Continued)

DECAY OF YELLOW PINE INDUCED BY LENZITES SAEPIARIA

I Culture block	II Volume (cc.)	III Weight before decay (gm.)	IV Specific gravity	V Weight after decay (gm.)	VI Per cent loss in weight due to decay	VII Per cent resin	VIII Per cent summer wood	IX Number growth rings per inch	X Inches from pith	XI Average specific gravity	XII Average per cent loss in weight
Longleaf pine (*Pinus palustris*)											
C4102	29.5	18.624	.631	17.930	3.72						
C4103	30.	18.805	.627	18.233	3.04						
C4104	32.5	19.830	.610	19.394	2.20						
C4105	31.5	18.760	.595	18.600	.85						
D4101	27.	15.403	.571	15.400	.02	13.92	22.	10.	1.0	.623	2.63
D4104	27.5	17.442	.634	17.345	.56						
D4105	26.	17.295	.664	16.031	7.31						
E4101	28.4	15.665	.552	14.286	8.80	12.52	25.	10.	1.5	.561	5.16
E4102	29.1	15.751	.541	15.021	4.64						
E4103	28.	15.390	.549	14.705	4.45						
E4104	27.	15.345	.568	14.693	4.25						
E4105	25.9	15.410	.595	14.847	3.65						
F4101	27.	15.182	.514	14.979	1.34	23.08	25.	10.	1.5	.545	.78
F4102	28.5	15.883	.516	15.814	.44						
F4103	28.	15.455	.541	15.318	.89						
F4104	28.	15.585	.538	15.410	1.12						
F4105	28.	15.883	.556	15.867	.10						
G4101	27.6	16.492	.586	16.409	.50	11.02	27.	9.	2.	.592	1.17
G4102	27.9	16.669	.590	16.578	.55						
G4103	26.5	16.810	.596	16.233	3.44						
G4104	27.5	16.888	.584	16.702	1.10						
G4105	28.2	17.820	.603	17.775	.25						
I 4101	27.	14.857	.532	14.707	1.01	16.84	25.	9.5	2.25	.560	1.21
I 4102	27.	14.964	.536	14.886	.52						
I 4103	26.4	14.801	.545	14.732	.47						
I 4104	30.8	17.420	.565	17.102	1.83						
I 4105	29.8	18.600	.624	18.184	2.24						
J 4101	26.8	14.689	.557	13.480	8.23	7.6	25.	9.	2.25	.561	8.63
J 4102	27.	15.080	.558	13.700	9.16						
J 4103	26.	14.657	.564	13.506	7.86						
J 4104	29.5	16.753	.567	15.200	9.28						
K4102	26.	14.220	.547	14.017	1.43	3.52	25.	9.	2.5	.538	3.45
K4103	25.4	13.706	.539	12.840	6.32						
K4104	29.4	15.366	.523	14.487	5.72						
K4105	27.	15.704	.582	15.650	.34						
L4102	28.4	16.117	.567	15.312	4.99	5.96	28.	13.	3.	.564	4.87
L4103	27.	15.248	.565	14.467	5.12						
L4104	31.4	17.327	.552	16.444	5.09						
L4105	29.	16.557	.571	15.850	4.27						
M4101	27.8	17.405	.626	17.314	.52	8.92	28.	14.	3.25	.566	.70
M4102	27.7	15.529	.561	15.521	.05						
M4103	26.	14.267	.549	14.085	1.28						
M4104	28.5	15.870	.556	15.611	1.63						
M4105	26.	14.062	.541	14.057	.04						
N4101	26.	15.367	.591	14.632	4.78	9.52	28.	13.	3.5	.595	3.15
N4102	26.	15.388	.592	14.630	4.93						
N4103	24.8	14.685	.592	14.401	1.94						

TABLE I (Continued)

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Longleaf pine (*Pinus palustris*)											
N4104	27.8	16.667	.599	16.380	1.72						
N4105	24.	14.440	.602	14.107	2.30						
O4101	28.	15.747	.562	15.629	.75	19.64	27.	14.	3.5	.571	1.25
O4102	27.2	15.350	.564	15.146	1.33						
O4103	27.3	15.206	.557	15.052	1.01						
O4104	26.7	14.760	.553	14.497	1.78						
O4105	26.	16.090	.619	15.872	1.36						
P4101	32.	18.390	.574	18.327	.34	7.84	27.	13.	3.75	.577	2.88
P4102	30.	17.556	.585	16.705	4.85						
P4104	30.	17.182	.572	16.592	3.44						
B4201	27.8	18.073	.650	17.752	1.78	22.34	30.	18.	1.00	.667	1.43
B4202	29.	18.772	.647	18.416	1.90						
B4203	31.	22.690	.699	22.092	2.64						
B4204	30.	19.760	.658	19.652	.55						
B4205	31.	21.799	.683	21.735	.29						
F4201	26.6	16.505	.620	16.076	2.60	9.54	30.	16.	2.25	.617	.88
F4203	28.	17.156	.613	17.150	.04						
F4205	28.3	17.524	.619	17.522	.01						
G4201	30.	19.192	.639	16.943	11.72	4.84	30.	16.	2.75	.645	8.70
G4203	31.	20.127	.649	18.811	6.54						
G4205	31.3	20.241	.647	18.650	7.86						
K4201	24.3	14.983	.616	14.893	.60	4.94	32.	15.	3.25	.603	.68
K4202	25.	14.884	.595	14.778	.71						
K4203	27.	16.130	.597	16.011	.74						
K4204	26.	15.718	.604	15.644	.47						
K4205	27.	16.344	.605	16.198	.89						
L4201	28.3	18.238	.645	18.235	.02	3.52	32.	23.	4.	.648	5.14
L4202	28.6	18.918	.661	18.912	.03						
L4203	26.8	17.523	.654	16.410	6.35						
L4204	25.8	16.528	.641	15.206	8.00						
L4205	24.8	15.860	.640	14.072	11.28						
N4201	28.	18.013	.643	17.047	5.36	4.30	32.	29.	4.	.628	1.79
N4204	26.7	16.541	.619	16.540	.01						
N4205	27.	16.838	.624	16.835	.02						
O4201	28.	17.052	.609	16.220	4.88	3.24	25.	24.	3.75	.598	8.80
O4202	28.	16.808	.600	15.703	6.57						
O4203	26.	15.432	.594	14.600	5.39						
O4204	26.2	15.662	.597	13.630	12.98						
O4205	25.6	15.186	.593	13.027	14.21						
P4202	27.	16.302	.604	13.810	15.28	5.6	25.	30.	4.5	.590	10.30
P4204	25.2	14.797	.587	12.485	15.61						
P4205	25.4	14.732	.580	14.730	.01						

SERIES B

In this series lettered columns of blocks chosen from the same samples of longleaf, shortleaf, and loblolly pine as employed in series A, were used. Five culture blocks were used in each column of blocks, and numbers 1 and 5 were left in their natural condition, while from 2, 3, and 4 the resin was extracted. The blocks were all labeled as described above, and those from which the resin was to be extracted were placed in a large 3-liter flask containing benzol. To this flask was connected a reflux condensor, and the benzol boiled. The benzol was changed from time to time until no resin was obtained when 100 cc. of the benzol in which the blocks had boiled for 10 hours was distilled. These resin-free culture blocks were then placed in an electric oven and dried for 10 days at 65° C. Cultures were prepared in the same way as in series A, and the controls and the resin-free blocks were segregated. All were inoculated with *Lenzites saepiaria*. The results obtained are given in table II. The percentage of loss in weight of the resin-free blocks, of course, is based on the weight of the blocks after the resin was extracted. The results of the experiment are very striking, for on the average the percentage loss in weight is greater in the control blocks containing resin than in the resin-free blocks. It may be that the vigorous and continued boiling in benzol had such an effect on the lignin as to prevent decay. However, in series C where the blocks were soaked in benzol for a few hours the benzol seemed to have no such effect on the growth of the fungus. On the other hand, it may be that benzol dissolves out other substances which aid in the nutrition of fungi within the woody tissues. Time has not permitted a repetition of series B, and until such is done we hesitate to place much stress on this phase of the work.

TABLE II (Series B)

EFFECT ON THE GROWTH OF LENZITES SAEPIARIA OF EXTRACTING BENZOL-SOLUBLE SUBSTANCES FROM YELLOW PINE WOOD

I	II	III	IV	V	VI	VII	VIII	IX
Longleaf pine (*Pinus palustris*)			Shortleaf pine (*Pinus echinata*)			Loblolly pine (*Pinus Taeda*)		
Culture block	Per cent loss in weight	Per cent resin	Culture block	Per cent loss in weight	Per cent resin	Culture block	Per cent loss in weight	Per cent resin
H3101	3.52	16.68	A4301	3.22	3.74	A2001	10.04	17.4
H3102	0.04	0.0	A4302	0.32	0.0	A2002	0.02	0.0
H3103	0.14	0.0	A4303	0.41	0.0	A2003	0.02	0.0
H3104	0.04	0.0	A4304	0.06	0.0	A2004	0.09	0.0
H3105	6.42	16.68	A4305	3.81	3.74	A2005	7.56	17.4
G3201	1.85	24.48	B4301	3.24	4.08	A2101	2.28	3.28
G3202	0.88	0.0	B4302	0.40	0.0	A2102	2.92	0.0
G3203	0.15	0.0	B4303	0.89	0.0	A2103	2.93	0.0
G3204	0.95	0.0	B4304	0.02	0.0	A2104	4.82	0.0

TABLE II (Continued)

I	II	III	IV	V	VI	VII	VIII	IX
Longleaf pine (*Pinus palustris*)			Shortleaf pine (*Pinus echinata*)			Loblolly pine (*Pinus Taeda*)		
G3205	6.21	24.48	B4305	3.12	4.08	A2105	2.3	3.28
P3201	9.19	22.26	C4401	6.64	3.94	A2201	29.9	6.4
P3202	0.13	0.0	C4402	1.20	0.0	A2202	2.74	0.0
P3203	0.91	0.0	C4403	1.23	0.0	A2203	3.52	0.0
P3204	0.27	0.0	C4404	3.29	0.0	A2204	2.91	0.0
P3205	8.06	22.26	C4405	5.04	3.94	A2205	16.15	6.4
F3301	8.70	5.78	F4401	2.64	3.58	A2301	24.3	18.56
F3302	1.60	0.0	F4402	0.02	0.0	A2302	2.78	0.0
F3303	3.36	0.0	F4403	0.03	0.0	A2303	2.72	0.0
F3305	7.48	5.78	F4404	0.09	0.0	A2304	3.73	0.0
O3401	0.03	5.50	F4405	2.18	3.58	A2305	29.0	18.56
O3402	0.80	0.0	D4501	4.22	3.66	H2301	11.93	3.08
O3403	0.41	0.0	D4502	1.23	0.0	H2302	2.47	0.0
O3404	0.39	0.0	D4503	1.62	0.0	H2303	3.10	0.0
O3405	0.60	5.50	D4504	1.58	0.0	H2304	4.06	0.0
L3501	0.06	5.8	D4505	4.83	3.66	H2305	9.39	3.08
L3502	0.33	0.0	F4501	2.39	3.84	D2401	8.74	4.68
L3503	0.40	0.0	F4502	1.56	0.0	D2402	7.09	0.0
L3504	0.49	0.0	F4503	3.39	0.0	D2403	5.51	0.0
L3505	0.28	5.8	F4504	1.27	0.0	D2404	5.68	0.0
H3601	6.74	15.72	F4505	6.86	3.84	D2405	6.24	4.68
H3602	0.92	0.0	....	....	....	F2401	13.00	5.00
H3603	1.26	0.0	....	....	....	F2402	0.64	0.0
H3604	1.33	0.00	....	....	....	F2403	1.05	0.0
H3605	4.96	15.72	....	....	....	F2404	0.41	0.0
O3701	3.94	3.96	....	....	....	F2405	8.83	5.00
O3702	2.10	0.0	....	....	....	A2501	41.8	7.28
O3703	1.28	0.0	....	....	....	A2502	0.02	0.0
O3704	2.68	0.0	....	....	....	A2503	0.01	0.0
O3705	3.23	3.96	....	....	....	A2504	1.25	0.0
E3801	13.5	25.58	....	....	....	A2505	47.3	7.28
E3802	1.61	0.0	....	....	....	A2601	9.47	5.10
E3803	0.81	0.0	....	....	....	A2602	0.02	0.0
E3804	0.04	0.0	....	....	....	A2603	1.03	0.0
E3805	12.93	25.58	....	....	....	A2604	7.30	0.0
G3901	14.67	15.16	....	....	....	A2605	9.97	5.10
G3902	5.46	0.0	....	....	....	A2701	3.49	3.36
G3903	0.27	0.0	....	....	....	A2702	0.02	0.0
G3904	0.50	0.0	....	....	....	A2703	0.01	0.0
G3905	10.36	15.16	....	....	....	A2704	0.06	0.0
P4001	5.04	5.78	....	....	....	A2705	5.20	3.36
P4002	0.37	0.0	....	....	....	A2801	7.83	10.5
P4003	0.41	0.0	....	....	....	A2802	0.03	0.0
P4004	1.40	0.0	....	....	....	A2803	0.01	0.0
P4005	7.21	5.78	....	....	....	A2804	0.48	0.0
H4101	3.03	4.70	....	....	....	A2805	12.70	10.5
H4102	0.35	0.0	....	....	....	A2901	6.10	3.72
H4103	0.44	0.0	....	....	....	A2902	0.05	0.0
H4104	0.23	0.0	....	....	....	A2903	0.06	0.0
H4105	25.80	4.7	....	....	....	A2904	0.11	0.0
E4201	11.58	4.52	....	....	....	A2905	7.68	3.72
E4202	0.99	0.0	....	....	....	A3001	3.18	4.18
E4203	1.98	0.0	....	....	....	A3002	0.03	0.0
E4204	0.35	0.0	....	....	....	A3003	0.07	0.0
E4205	25.15	4.52	....	....	....	A3004	0.02	0.0
....	....	....	....	....	....	A3005	2.88	4.18

SERIES C

For this series blocks of yellow poplar (*Liriodendron tulipifera*) were cut the same size as for the cultures of series A and B. They were all taken from the same piece of sapwood and were all of approximately the same specific gravity. They were dried to constant weight at 65° C. and weighed. Twelve dilutions of resin in benzol were prepared, containing from 0 to 10 per cent resin. Seven of the blocks were immersed in each of these resin solutions, which were heated to boiling to drive the air out of the blocks. When the solution had cooled it was driven into the blocks, impregnating them with various amounts of resin. The blocks were then removed to an electric oven where they remained at room temperature for several hours, while a greater part of the benzol evaporated, after which they were dried at 65° C. and weighed. Control blocks without resin were also used and all were placed in cultures as described for series A. All were inoculated with *Lenzites saepiaria* and were incubated for one year.

TABLE III (Series C)

DECAY OF RESIN-IMPREGNATED YELLOW POPLAR BLOCKS INDUCED BY LENZITES SAEPIARIA

Culture block	Weight before decay (gm.)	Weight after decay (gm.)	Per cent loss in weight	Per cent resin
O 1	12.093	7.894	34.70	*0
O 2	11.360	9.777	13.95	*0
O 3	12.636	10.916	13.60	*0
O 4	11.525	10.690	7.25	*0
O 5	11.193	9.182	17.96	*0
O 6	13.793	10.915	20.87	*0
O 7	13.451	8.517	36.70	*0
P 1	13.007	8.276	36.40	0.87
P 2	13.085	8.012	38.80	0.74
P 3	9.636	5.161	46.50	0.27
P 4	10.888	8.009	26.40	0.27
P 5	10.236	6.692	34.63	0.03
P 6	11.827	7.257	38.70	0.17
P 7	13.581	8.750	35.50	0.41
Q 1	13.181	8.706	33.95	0.88
Q 2	12.710	9.545	24.90	0.57
Q 3	11.785	8.765	25.60	0.00
Q 4	10.075	8.226	18.35	0.50
Q 5	11.400	8.675	23.90	0.43
Q 6	11.393	8.845	22.40	0.54
Q 7	13.208	8.521	35.50	0.48
R 1	13.153	9.580	27.15	0.29

* Soaked in benzene without resin.

TABLE III (Continued)

Culture block	Weight before decay (gm.)	Weight after decay (gm.)	Per cent loss in weight	Per cent resin
R 2	10.532	8.187	22.30	1.99
R 3	12.695	9.552	24.80	1.47
R 4	13.286	10.048	24.40	1.73
R 5	12.792	10.531	17.70	0.31
R 6	13.911	10.136	27.15	1.39
R 7	10.858	7.840	27.8	0.00
S 1	13.058	9.550	26.9	1.76
S 2	11.250	10.594	5.83	2.38
S 3	11.442	8.888	22.34	2.10
S 4	13.199	11.871	10.07	2.19
S 5	12.332	11.576	6.14	1.64
S 6	10.680	10.275	3.79	2.13
S 7	11.323	10.630	6.13	2.00
T 1	13.290	9.148	31.15	2.85
T 2	13.117	8.844	32.60	3.17
T 3	12.509	9.488	24.15	2.80
T 4	13.404	9.746	27.30	2.41
T 5	12.274	7.450	39.30	3.48
T 6	12.693	10.631	16.25	2.75
T 7	14.344	8.779	38.80	3.07
U 1	12.983	12.053	7.18	0.92
U 2	13.397	12.363	7.72	2.59
U 3	14.073	13.596	3.39	5.18
U 4	13.320	12.139	8.87	6.55
U 5	13.051	12.120	7.14	3.23
U 6	12.269	10.901	11.15	1.79
U 7	11.283	8.425	25.30	2.25
V 1	11.832	8.055	31.94	4.04
V 2	12.215	9.500	22.25	4.30
V 3	14.045	9.448	32.70	3.29
V 4	10.814	8.317	23.10	1.85
V 5	11.465	7.518	34.50	4.52
V 6	11.511	8.946	22.30	5.20
V 7	12.435	7.368	40.70	1.66
W 1	11.384	7.352	35.40	7.18
W 2	12.190	8.411	31.00	6.52
W 3	11.007	9.530	13.40	5.67
W 4	11.773	9.677	17.80	6.02
W 5	11.302	10.165	10.06	7.11
W 6	14.147	7.790	45.00	5.25
W 7	14.572	7.582	48.00	5.33
X 1	13.154	8.177	37.80	7.55
X 2	11.942	8.554	28.30	5.25
X 3	11.652	7.565	35.00	3.49
X 4	11.603	9.376	19.20	7.84
X 5	12.320	8.205	33.40	5.56
X 6	11.874	9.497	20.00	7.82
X 7	12.695	7.791	38.60	6.07
Y 1	13.594	8.646	36.40	8.45
Y 2	15.290	10.744	29.70	7.80
Y 3	13.248	9.624	27.30	7.21
Y 4	12.915	10.770	16.60	6.76
Y 5	11.224	9.424	16.00	9.33
Y 6	13.502	7.515	44.40	10.18
Y 7	13.032	7.158	45.10	8.30
Z 1	15.685	9.021	42.60	8.28
Z 2	12.785	7.480	41.50	13.62

TABLE III (Continued)

DECAY OF RESIN-IMPREGNATED YELLOW POPLAR BLOCKS INDUCED BY LENZITES SAEPIARIA

Culture block	Weight before decay (gm.)	Weight after decay (gm.)	Per cent loss in weight	Per cent resin
Z 3	11.889	8.855	25.50	12.34
Z 4	13.368	6.485	51.50	11.64
Z 5	12.561	7.268	42.10	10.45
Z 6	14.133	8.060	43.00	10.84
Z 7	14.838	8.407	43.40	8.18
YZ 1	12.032	10.806	10.20	† 0
YZ 2	12.320	11.400	7.46	† 0
YZ 3	13.230	11.983	9.41	† 0
YZ 4	10.642	9.716	8.70	† 0
YZ 5	10.259	9.515	7.25	† 0
YZ 6	10.923	10.135	7.21	† 0
YZ 7	12.005	10.220	14.90	† 0

† Not treated with benzene.

SERIES D

Series D was prepared in exactly the same way as series C, but the cultures were inoculated with *Polystictus hirsutus,* a fungus usually found on hard woods. The incubation period was one year. Table IV shows the results of this series.

TABLE IV (Series D)

DECAY OF RESIN-IMPREGNATED YELLOW POPLAR BLOCKS INDUCED BY POLYSTICTUS HIRSUTUS

Culture block	Weight before decay (gm.)	Weight after decay (gm.)	Per cent loss in weight	Per cent resin
O 8	14.052	13.800	1.79	* 0
O 9	12.166	11.892	2.25	* 0
O 10	10.844	10.585	2.38	* 0
O 11	10.817	10.636	1.67	* 0
O 12	11.164	11.972	1.72	* 0
O 13	13.265	13.001	1.99	* 0
O 14	12.253	11.942	2.53	* 0
P 8	11.248	10.607	5.69	0.11
P 9	12.246	10.275	16.09	0.51
P 10	11.612	9.538	17.85	0.66
P 11	12.944	10.398	19.68	0.31
P 12	10.957	8.563	21.82	0.60
P 13	10.109	9.422	6.80	0.47
P 14	11.611	9.170	21.02	0.83
Q 8	12.776	10.020	21.58	0.38
Q 9	10.770	8.992	16.50	0.64
Q 10	11.067	8.940	19.24	0.69
Q 11	10.330	8.949	13.37	0.58
Q 12	11.386	8.750	23.15	0.97
Q 13	11.107	8.075	27.29	1.10
Q 14	12.150	10.048	17.30	1.22

* Soaked in benzene without resin.

TABLE IV (Continued)

Culture block	Weight before decay (gm.)	Weight after decay (gm.)	Per cent loss in weight	Per cent resin
R 8	12.994	11.022	15.17	1.27
R 9	12.493	10.507	15.90	0.10
R 10	11.285	9.830	12.89	1.28
R 11	11.305	9.360	17.20	0.57
R 12	11.653	8.770	24.76	1.30
R 13	12.434	10.425	16.15	0.11
R 14	10.879	10.651	2.10	1.43
S 8	10.247	6.955	32.10	2.74
S 9	10.375	7.821	24.60	2.15
S 10	12.270	8.438	31.22	1.79
S 11	12.630	9.010	38.62	1.92
S 12	11.584	7.853	32.21	2.65
S 13	11.209	7.071	36.90	2.76
S 14	12.030	8.891	26.10	3.20
T 8	13.401	10.001	25.38	3.22
T 9	12.187	9.220	24.40	3.62
T 10	12.577	9.393	25.40	2.42
T 11	13.520	10.812	20.01	4.01
T 12	12.872	9.905	23.07	2.71
T 13	11.840	10.002	15.51	4.95
T 14	12.154	10.360	14.78	3.09
U 8	13.237	11.027	16.70	2.22
U 9	14.046	11.003	21.70	3.26
U 10	13.068	10.637	18.60	2.55
U 11	12.331	9.530	22.73	1.86
U 12	11.520	8.257	28.35	1.20
U 13	12.288	9.445	23.18	2.25
U 14	12.846	10.031	21.90	3.02
V 8	13.093	10.160	22.40	2.39
V 9	13.070	10.210	21.90	5.36
V 10	11.779	8.510	27.80	3.70
V 11	10.624	8.785	17.30	3.68
V 12	15.300	11.336	25.90	2.45
V 13	14.252	11.200	24.40	4.13
V 14	13.279	9.970	25.00	3.52
W 8	12.064	10.506	12.90	6.12
W 9	14.508	11.836	18.40	5.55
W 10	13.722	11.175	18.58	5.62
W 11	11.527	8.844	23.26	6.00
W 12	11.205	8.366	25.33	6.50
W 13	11.682	9.560	18.16	7.20
W 14	10.651	8.140	23.60	6.16
X 8	12.661	10.466	17.30	9.60
X 9	13.936	9.530	31.60	2.16
X 10	13.444	10.223	23.99	4.73
X 11	10.970	9.066	17.38	6.05
X 12	11.648	9.148	21.45	7.24
X 13	13.160	10.820	17.80	5.06
X 14	13.179	10.690	18.90	4.56
Y 8	13.708	12.330	10.03	8.44
Y 9	14.807	11.843	20.01	7.88
Y 10	12.500	10.541	15.68	10.80
Y 11	12.582	9.957	20.90	7.95
Y 12	13.010	10.926	16.02	7.53
Y 13	12.685	9.587	24.42	9.60
Y 14	13.702	11.294	17.60	8.05
Z 8	15.524	15.402	7.85	8.77

TABLE IV (Continued)

DECAY OF RESIN-IMPREGNATED YELLOW POPLAR BLOCKS INDUCED BY POLYSTICTUS HIRSUTUS

Culture block	Weight before decay (gm.)	Weight after decay (gm.)	Per cent loss in weight	Per cent resin
Z 9	12.769	12.731	0.30	12.41
Z 10	11.781	11.257	4.45	13.20
Z 11	15.329	15.108	1.44	10.40
Z 12	14.727	14.620	0.73	10.50
Z 13	11.832	9.903	16.30	13.48
Z 14	12.035	9.347	22.32	12.34
YZ 8	12.119	10.936	9.76	† 0
YZ 9	10.324	8.931	13.50	† 0
YZ 10	13.698	11.940	12.81	† 0
YZ 11	13.162	11.686	11.20	† 0
YZ 12	11.286	9.660	14.41	† 0
YZ 13	12.073	10.761	10.88	† 0
YZ 14	12.902	11.369	11.90	† 0
YZ 15	10.772	9.436	12.40	† 0

† Not treated with benzene.

DISCUSSION.

Before entering upon a discussion of the specific factors of wood which influence its resistance to decay, it might be well to call attention to some factors of the environment which influence fungous activity in general. In a problem of this kind, where the results depend on natural conditions and also to a certain extent on chance or probability of infection, the results may be misleading unless such factors are considered.

In any work where a host is inoculated with an organism one anticipates a certain percentage of failures, even though the host is susceptible and the parasite virulent. The chance of failure of infection seems to be even greater when we deal with the inoculation of woody rather than of more fleshy herbaceous plants; especially is this true when dealing with fungi attacking structural timber. In the cultures of *Lenzites saepiaria* on blocks of yellow pine, described above, the percentage of failure proved to be very high. The charts to be discussed below certainly show this to be a fact. It is true for sapwood as well as for heartwood, even though sapwood decays much more readily than heartwood. In the same column of blocks of the same sample one culture block may be considerably decayed and others not at all; for instance, in table I culture block E 1603 was reduced in weight by decay only 0.028 per cent, while the adjoining block, E 1604, was reduced 17.5 per cent; also G 1603 was reduced 0.14 per cent and G 1604 was reduced 17.4 per cent. Many other examples in table I could be given.

Another discrepancy in the data is the one already mentioned concerning the loss of resin in sterilization. The charts bring out this discrepancy very vividly. Take, for instance, the charts correlating resin content and specific gravity with percentage loss in weight during one year of incubation. If we consider here that a part or all of the loss in weight above 17.6 per cent resin is due to sterilization and that above a specific gravity of .70 to .75 (the average for longleaf pine) the extra weight is due to an excess of resin, the charts will at once show the error due to sterilization. In the general chart showing the relation of specific gravity to the percentage reduction in weight this is more evident than in the other charts. In this chart the values of the specific gravity are marked off on the primary ordinate, and the percentages of reduction in weight on the primary abscissa. As the specific gravity increases above .70 to .75 the curve formed by the plotted points gradually swings away from the primary ordinate. An examination of representative samples in this part of the chart reveals the fact that they have not been attacked in the least by the fungus. We are safe, then, to assume that, as far as loss of weight due to decay is concerned, the plotted points in this part of the chart can be moved over toward the primary ordinate.

Thus, these two factors, (1) the chance of failure of infection and (2) the loss of weight of highly resinous blocks due to sterilization, must be considered when attempting to draw conclusions from the various charts.

Charts Based on the Results of Series A.

In the charts plotted from the data obtained in series A the three species of pine are distinguished by symbols described in the keys of the various charts. A bar drawn through any of these symbols represents sapwood.

In all of these charts (I-IX), except chart IV, showing the relation of specific gravity to decay, each point represents an average for a column of culture blocks in the original samples. It was necessary to take these averages in cases where one of the factors concerned was a property of the whole column of blocks, such as resin content, percentage of summer wood, number of rings per inch, etc. In chart IV each point represents an individual culture block.

Resin as an index of durability.—Chart I shows the relation of the resin content of the wood to its decay. The percentages of resin are given on the primary ordinate and the percentages of loss in weight in one year on the primary abscissa. This chart shows two definite facts: (1) Sapwood decays in all three species irrespective of resin content. The maximum resin content for sapwood, however, was but 12.9 per cent with a loss in weight of about 13 per cent. (2) In the heartwood the resin content has no definite relation to resistance in any one of the three species of pine. If there is any relation to be recognized, however, it is apparent above 12 per cent resin, and even here both shortleaf and longleaf pine are reduced in weight 12.5 per cent. Even though the reduction in the upper part of the chart (above 18 per cent resin) may be due entirely to sterilization, the curve below that would be very steep, in fact, practically parallel to the ordinate.

Specific gravity as an index of durability.—Betts ('15) has shown that the density of pine wood depends upon the proportion of summer wood and spring wood in the annual growth rings. "In tests made on a number of small pieces of summer wood and spring wood whittled out separately from wide-ring pieces of loblolly pine, the . . . density of the summer wood came very close to being just twice that of the spring wood, so that the percentage of summer wood in the annual rings is an indication of weight."

Chart II shows very clearly that the specific gravity of the samples used in this work depends upon the percentage of summer wood. On the primary ordinate the values of specific gravity are represented and on the primary abscissa the percentages of summer wood. As the percentage of summer wood increases the specific gravity increases.

Chart III shows the relation between specific gravity and the percentage of resin. The values of the specific gravity are given on the primary ordinate and the percentages of resin on the primary abscissa. Above a specific gravity of .75 the resin content may influence the weight considerably, but below this weight there seems to be no definite relation in any of the species, the longleaf and shortleaf pine being mixed quite evenly.

Chart IV shows the relation of specific gravity to durability. On the primary abscissa are represented the percentages of loss in weight in one year and on the primary ordinate the values of the specific weights. As was mentioned above, in this case below .75 specific gravity, there is a high percentage of failures in inoculation, and consequently a congestion of plotted points along the primary ordinate in this region. Above .75 specific gravity the curve gradually swings away from the primary ordinate due to the loss of weight in sterilization. Thus, before considering the meaning of this chart it will be necessary to consider this upper portion of the chart with the points moved back toward the primary ordinate.

This chart was plotted on the basis of individual culture blocks, and shows that (1) sapwood decays irrespective of density or species; (2) there is a perceptible curve showing that irrespective of species the lighter heartwood decays more readily than the more dense heartwood; (3) loblolly pine, however, is generally lighter than longleaf and shortleaf pine, the two latter being fairly evenly distributed.

Chart V shows the same relation as illustrated in chart IV, but differs from the latter in that the plotted points represent averages for columns of culture blocks rather than the individual blocks. The general points brought out by this chart are the same as in chart IV, except that the curve for heartwood becomes more abrupt and the apparent increase of durability due to an increase of density becomes less evident here than in chart IV. However, the specific gravity of pine wood depends on the percentage of summer wood (chart II) and there is a tendency toward an increase in density with a greater number of growth rings per inch (chart VIII). These two facts, together with the results shown in charts VI and VII, indicate a more evident relation of density to durability than is represented by chart V.

Summer wood as an index of durability.—Chart VI shows the relation of the proportion of pine summer wood and spring wood to resistance to decay. Since density depends on the percentage of summer wood and durability seems to increase with an increase of density, it would be anticipated that with increased summer wood there would be increased decay resistance. Chart VI shows this to be true. A part of the longleaf pine containing between 45 and 55 per cent summer wood was very resinous, and in this chart these points farther out should be considerably thrown back toward the primary ordinate to correct for sterilization.

Chart VI shows that (1) sapwood decays irrespective of species of pine and also irrespective of summer wood; (2) the summer wood of the heartwood, on the other hand, shows a tendency to resist decay more than the spring wood, and is a fairly good index of durability; (3) shortleaf heartwood with a high percentage of summer wood is as resistant to decay as longleaf heartwood with high percentages of summer wood, and *vice versa.*

Width of the rings of growth as an index of durability.—Since in specifications for structural timber the width of the annual rings has been closely associated with rules for grading, which involve density, chart VII was plotted to show the relation of the number of annual growth rings per inch to decay. The number of rings per inch measured on a radius of the stem are represented on the primary ordinate and on the primary abscissa the percentage loss in weight due to decay.

The results are very similar to those noted in chart VI; that is, we may conclude that (1) the width of the rings in the sapwood of the three species of pine has little or no effect on the inroads of the fungus; (2) in a consideration of the heartwood, the more resistant growth rings are the narrower ones, irrespective of species; (3) below a density of .75 the number of rings per inch must be closely associated with specific gravity, that is, by correlating the results here with those of chart IV, there is an indication that narrower rings indicate denser, more durable wood than open wide rings. This, however, could not be absolute, for the wide rings are often more than 75 per cent summer wood. In such cases they are resistant to fungous attack.

Chart VIII shows the relation of the number of growth rings per inch to density. With the exception of those blocks having a density over .75 due to high resin content the tendency in this chart is to show an increased density as the width of the rings decrease.

Distance from the pith as an index of durability.—Chart IX shows that distance from the pith, or age of the heartwood, is no index of the durability of the heartwood. Tests were made on pieces up to 16 inches in diameter. The sapwood decays irrespective of distance from the pith.

SERIES B.

See description of series B and table II above.

SERIES C.

Chart x shows the relation of resin to the decay, induced by *L. saepiaria,* of yellow poplar blocks impregnated with resin. On the primary ordinate are represented the percentages of resin and on the primary abscissa the percentage loss in weight in one year. The plotted points are well scattered and show no definite course, unless there is a tendency to increase in percentage of decay with an increase of resin. When this is compared with chart xi, which shows the same relation for *Polystictus hirsutus,* there is an interesting contrast, for *Polystictus* seems to be inhibited, if anything, by resin. Although the points are well scattered, there is a tendency to show that *Lenzites* thrives more or less on benzol-soluble substances when infiltrated into the wood, while *Polystictus,* which usually grows on hard woods, does not.

CONCLUSIONS.

It would seem that, from the results of the preliminary experiments discussed above, it would be safe to conclude that:

(1) Resin is no safe index of the durability of the three species of yellow pine investigated. Resin is not only undesirable for specifying durability because it is no safe index of decay resistance, but also because of the expenditure of time and labor necessary to make resin percentage determinations.

(2) On the other hand, specific gravity or density of the wood materially influences resistance to decay of the heartwood, i. e., the more dense the wood the more durable it is, irrespective of the three species of wood examined.

(3) Specific gravity, however, is a property which can not be determined from inspection, but it can be estimated by recourse to the proportion of summer wood to spring wood in the growth rings, which proves to be a safe criterion of the durability of heartwood; i. e., an increase in summer wood results in an increase in specific gravity.

(4) The width of the growth rings furnishes a further index of durability, the narrower rings showing more resistance to fungous attack than broad, open rings.

(5) The age, or distance from the pith of heartwood, shows no relation to durability, at least up to 16 inches in diameter.

(6) Sapwood decays irrespective of resin content, specific gravity, width of the annual rings, or species of pine.

(7) Shortleaf heartwood or loblolly heartwood is as durable as longleaf heartwood, provided it has the same qualities as to specific gravity or density.

(8) Specifications for durability of the three species of pine considered should be based on a judicious combination of specific gravity, number of rings per inch, and the percentage of sapwood. In other words, where pieces of the highest lasting powers are desired it will be necessary to specify pieces of the greatest density and with a minimum

percentage of sapwood. For inspection purposes the specific gravity may be estimated by an examination of the percentage of summer wood. The more desirable pieces of timber are those containing broad bands of summer wood and narrow bands of spring wood as shown in the cross-section.

(9) The investigations thus far have been conducted to ascertain the toxic effect of resin on the fungous decay of wood. The results have shown that there are no toxic effects, but that there are other important relations of resin to decay, as, for instance, its waterproofing effect on wood and, thus, its influence on the absorption of moisture by wood containing it; that is, the power of wood to absorb moisture is very important in its decay. It is well known that below a certain minimum and above a certain maximum of moisture in wood *Lenzites saepiaria* and other similar fungi will not grow. Any property of the wood which will influence this balance of moisture is of importance in decay resistance. Thus, if the wood contains enough resin to have a material waterproofing effect it must play a role in durability. However, at present the percentage of resin necessary for such an influence is unknown. From the analyses given above it may be assumed that it is at least 5 per cent or more, but this would not be a safe basis for specifying decay resistance, since a piece of timber of low summer wood percentage (density) may contain this amount of resin, and yet be porous enough to be attacked by fungi. On the other hand, although not an absolute rule, it is generally true that a dense piece of heartwood showing dark summer wood is more liable to contain at least 5 per cent resin than is a lighter piece. Hence, specifications based on high percentage of summer wood in most cases would more nearly fulfill requirements for durability than those based on resin content, at least until more is known concerning the influence of resin on the moisture-absorbing power of wood. The relation of resin to the absorbing power of pine timbers and the optimum relative humidity of the air for the decay of resin-containing wood are problems for further investigations. When this work is taken up again due consideration will be given to correcting the error due to sterilization. At a later time the probable error of the mean when dealing with averages of the above data will be calculated and reported with the data taken from cultures incubated for a two-year period.

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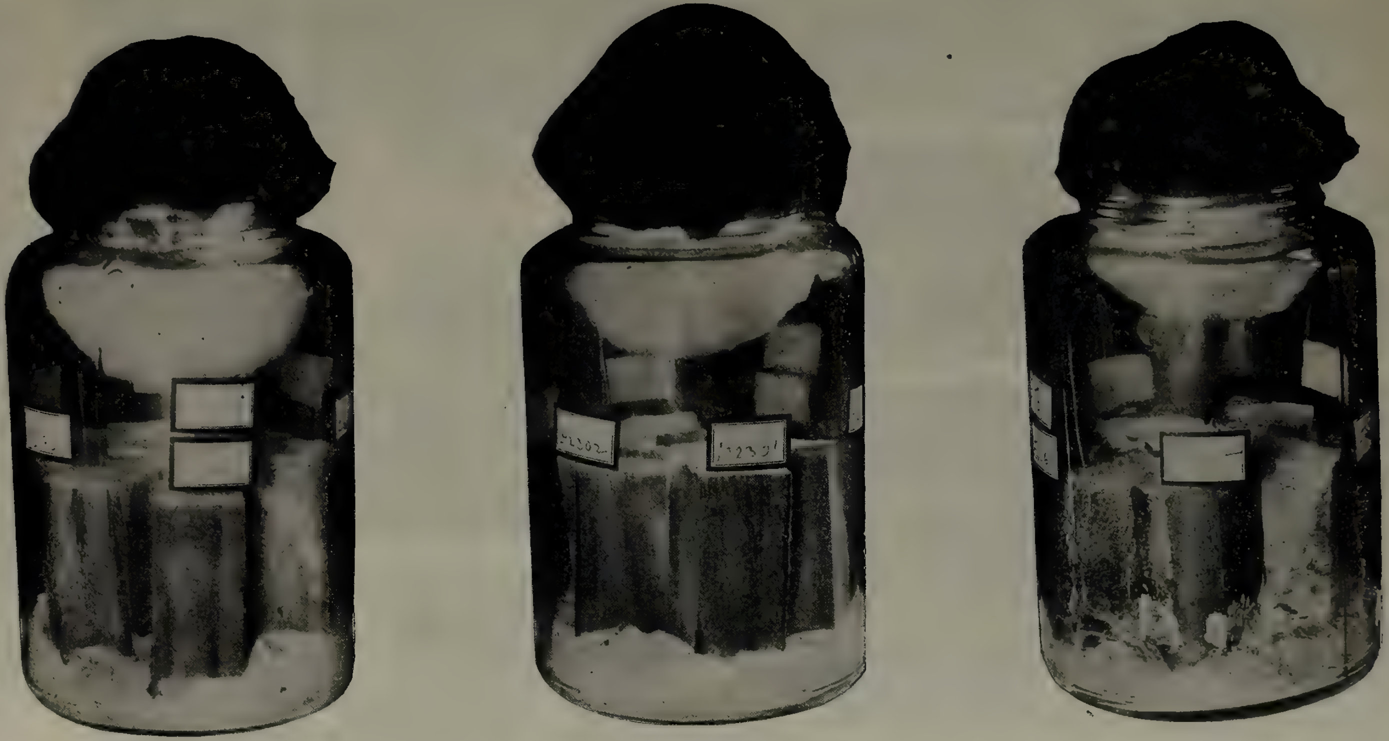

Plate 9.

Showing the position of the blocks in culture, the method of plugging the jars for sterilization, etc.

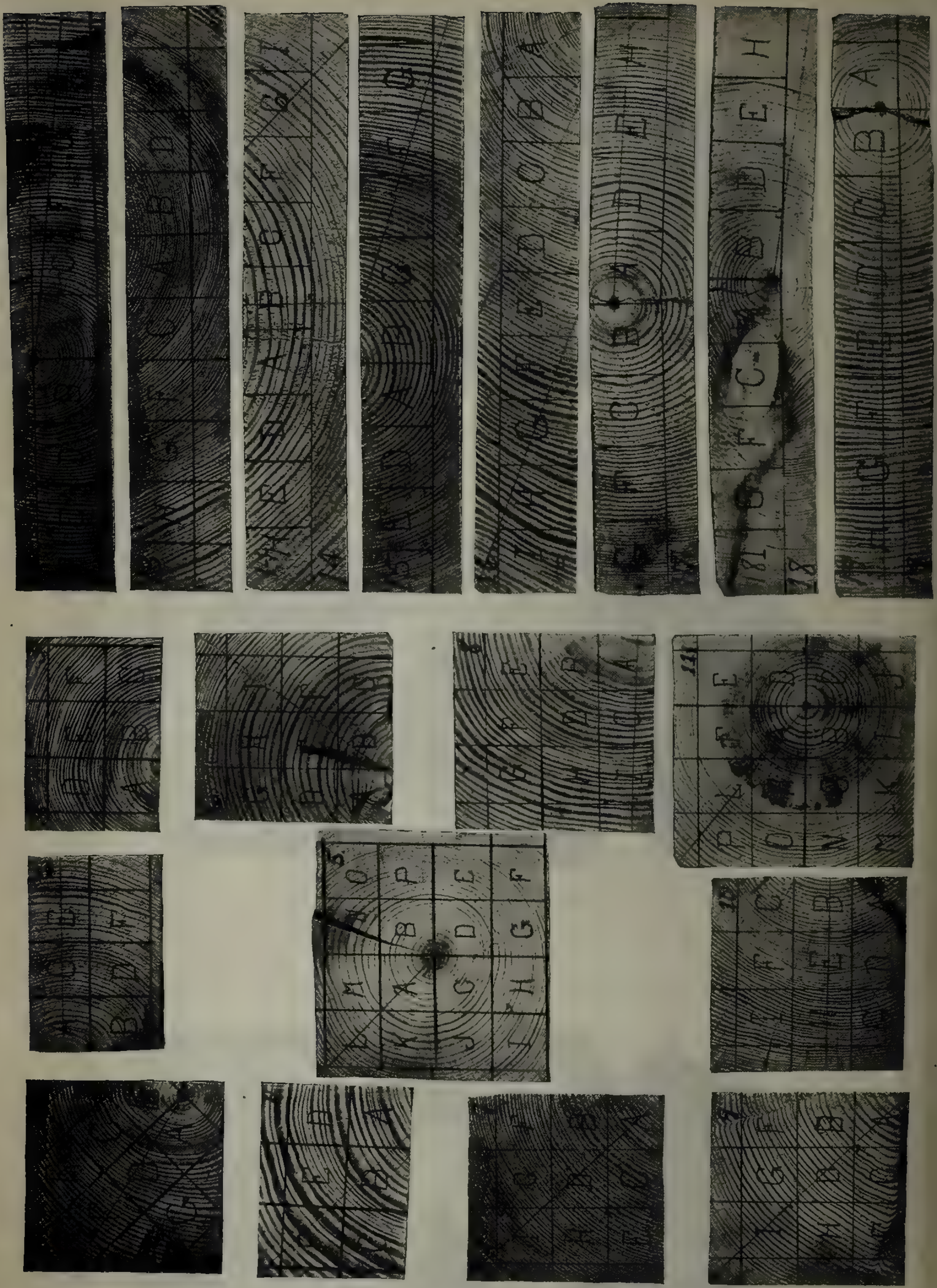

PLATE 10.

The original samples of pine (Nos. 1-19), marked off into squares one inch on a side and labeled with a letter representing the various columns of culture blocks given in table I. Numbers 1-11 are shortleaf pine (*Pinus echinata*) and Nos. 12-19 are longleaf pine (*P. palustris*).

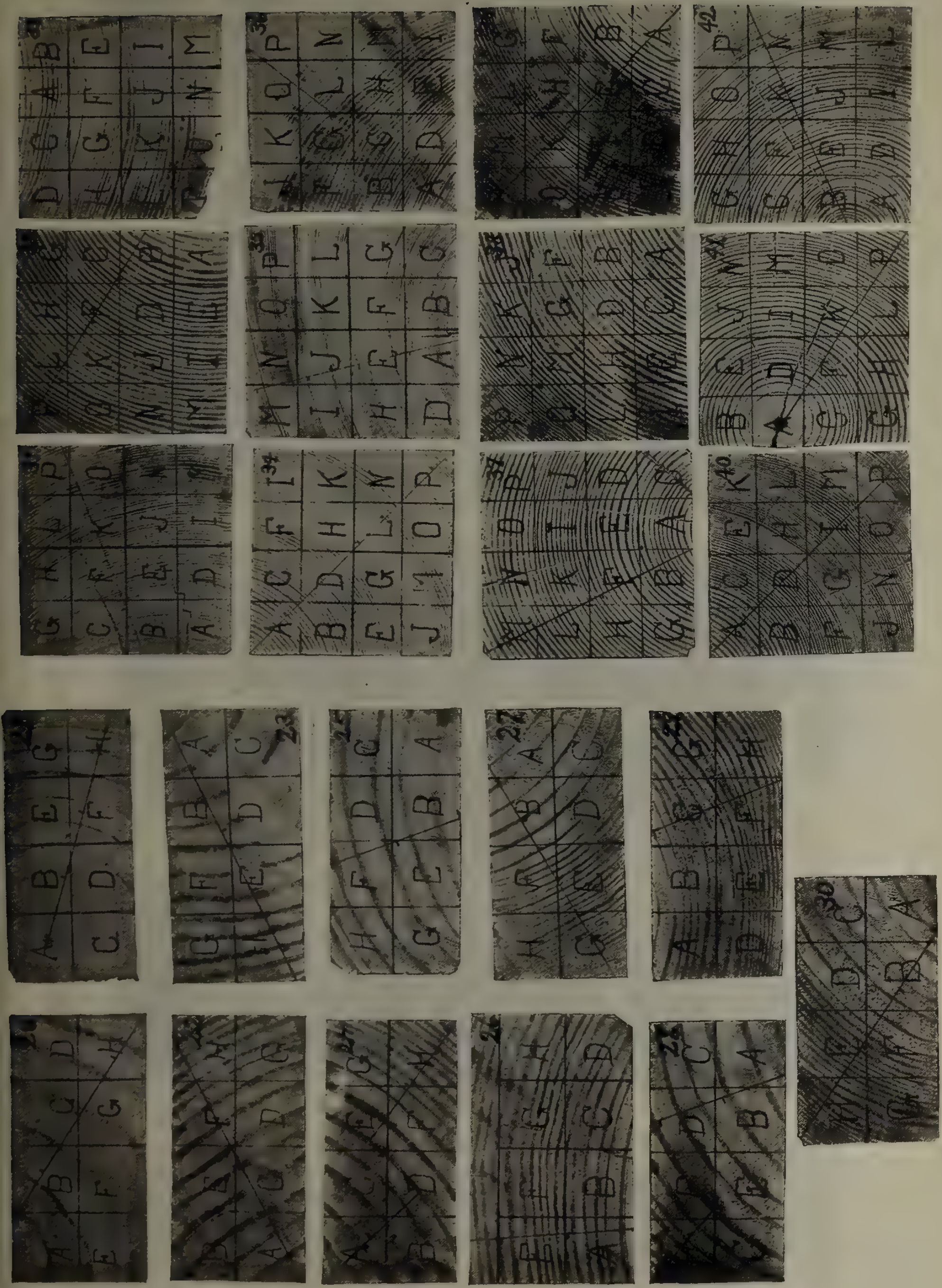

PLATE 11.

The original samples Nos. 31-42. Samples 20-30 are loblolly pine (*Pinus Taeda*) and 31-42 are longleaf pine (*P. palustris*).

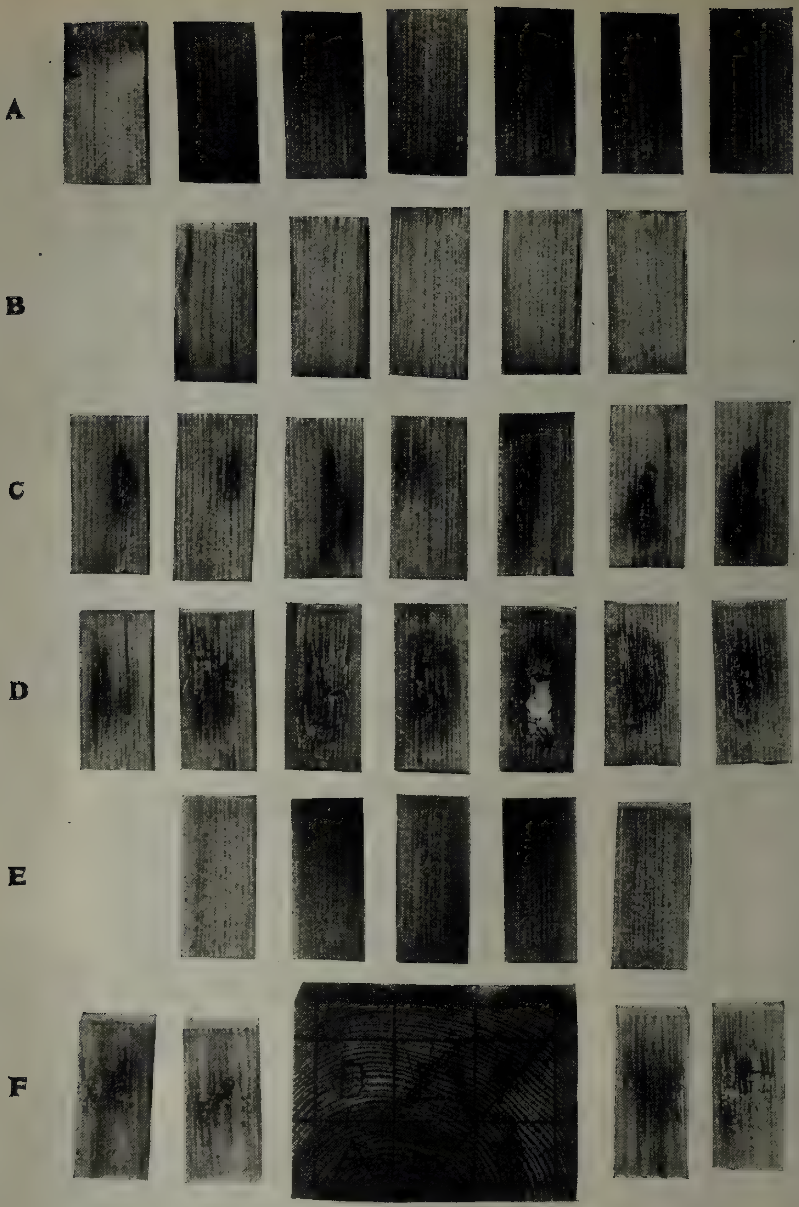

PLATE 12.

The original sample No. 3 of shortleaf pine together with sections of the culture blocks, which were split after *Lenzites saepiaria* had grown upon them for one year. Samples from the columns A, B, C, D, E, and F are shown; columns A, B, and E are all, or nearly all, heartwood, while C, D, and F are nearly all sapwood. This shows graphically the decay of the sapwood and the resistance of the heartwood in comparison. The average specific gravity, average decay, and resin content of the columns are given here for reference.

Column	Resin percentage	Specific gravity	Decay percentage
A	4.8	.653	6.12
B	2.8	.665	2.12
C	3.3	.705	11.73
D	2.5	.658	22.30
E	3.2	.686	5.69
F	2.1	.624	17.68

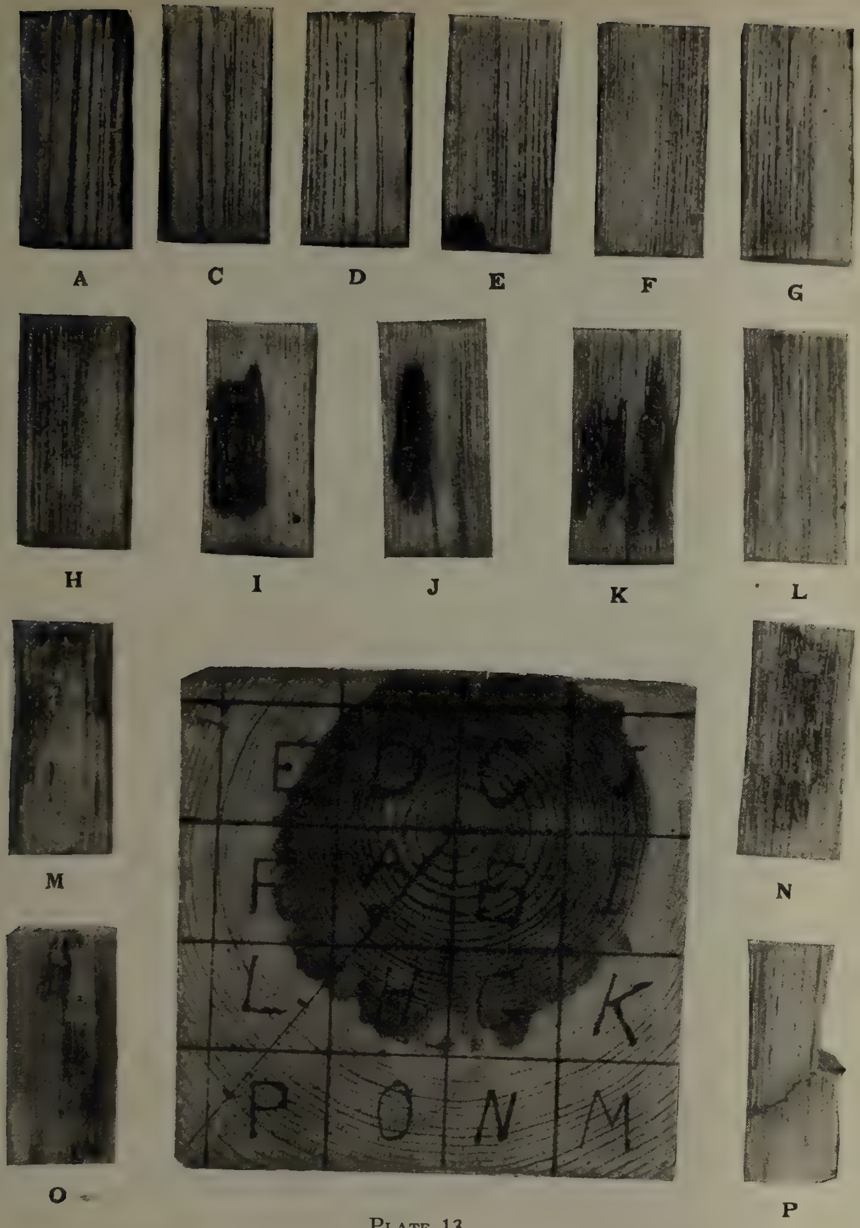

PLATE 13.

The original sample No 11 of shortleaf pine together with split sections of the culture blocks chosen from the various columns as labeled. As in pl. 12, the resistance of the heartwood to fungous decay is shown. The average specific gravity, average decay, and resin content of the various columns are given herewith:

Column	Resin percentage	Specific gravity	Decay percentage
A	22.98	.674	5.90
C	18.50	.646	3.84
D	21.04	.682	8.68
E	14.32	.526	5.36
F	10.64	.495	3.34
G	8.94	.539	6.75
H	25.34	.551	5.25
I	18.30	.469	11.60
J	13.38	.487	12.40
K	2.04	.428	31.80
L	1.36	.433	54.30
M	1.44	.426	57.10
N	1.26	.433	30.51
O	3.56	.453	21.10
P	3.24	.461	52.50

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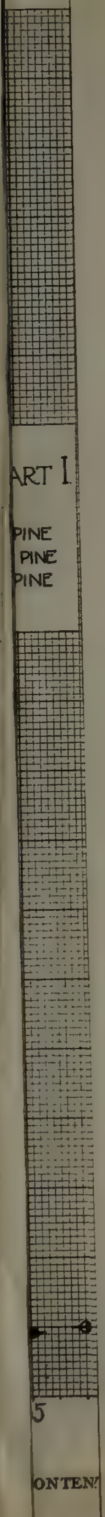

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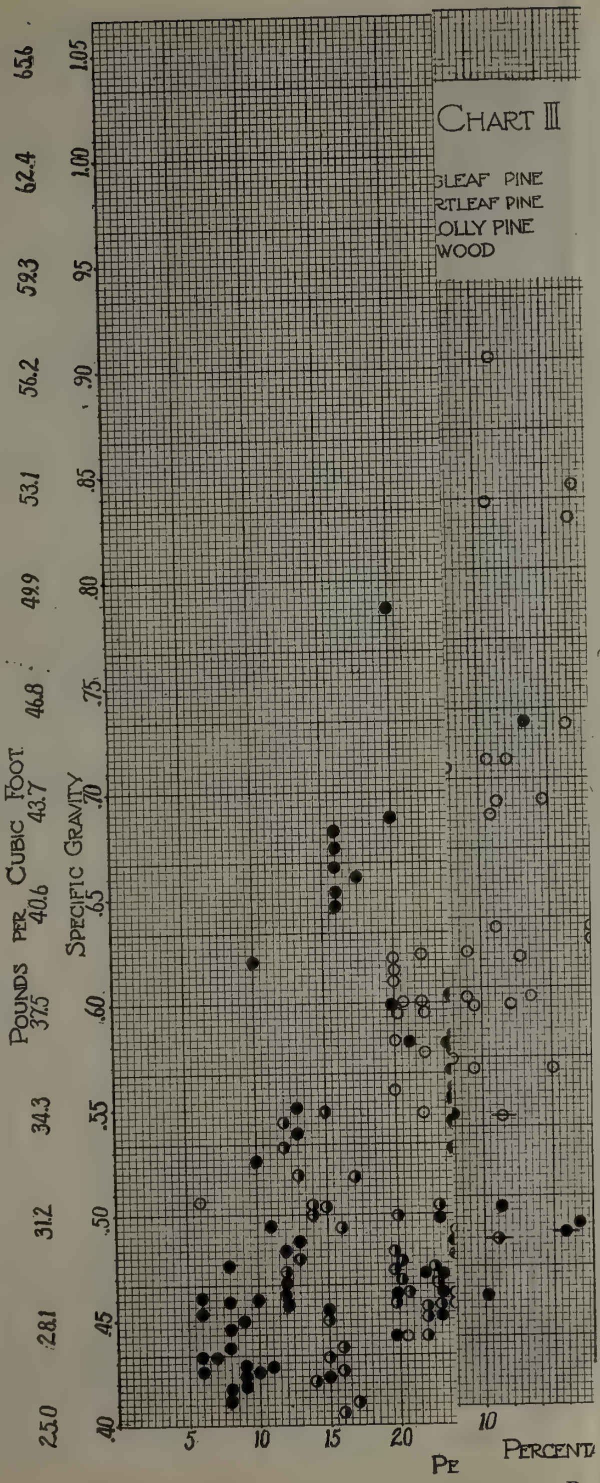

Chart II. Showing that /ing the Re

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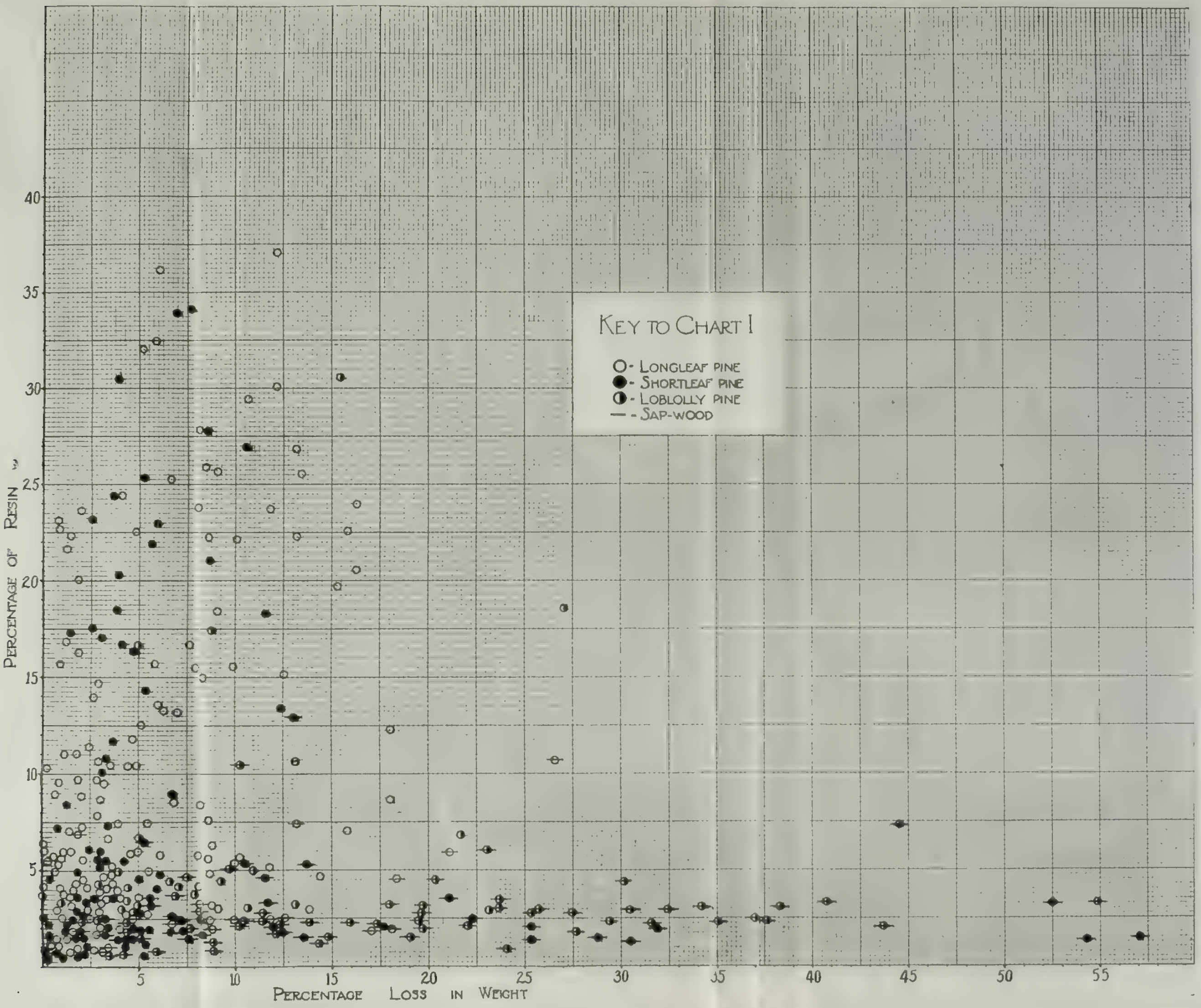

Chart I. Showing the Relation of Resin Content to Decay.

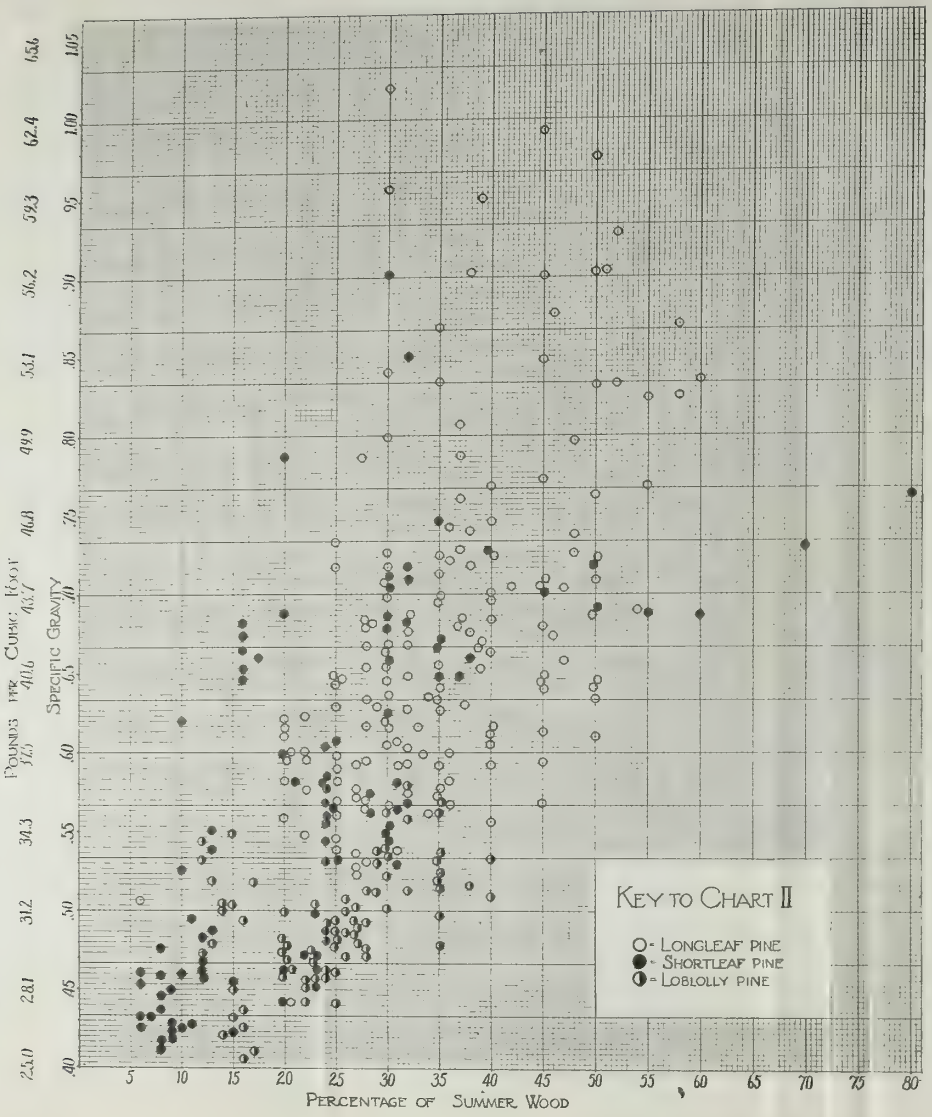

Chart II. Showing that Specific Gravity Depends on the Percentage of Summer Woo

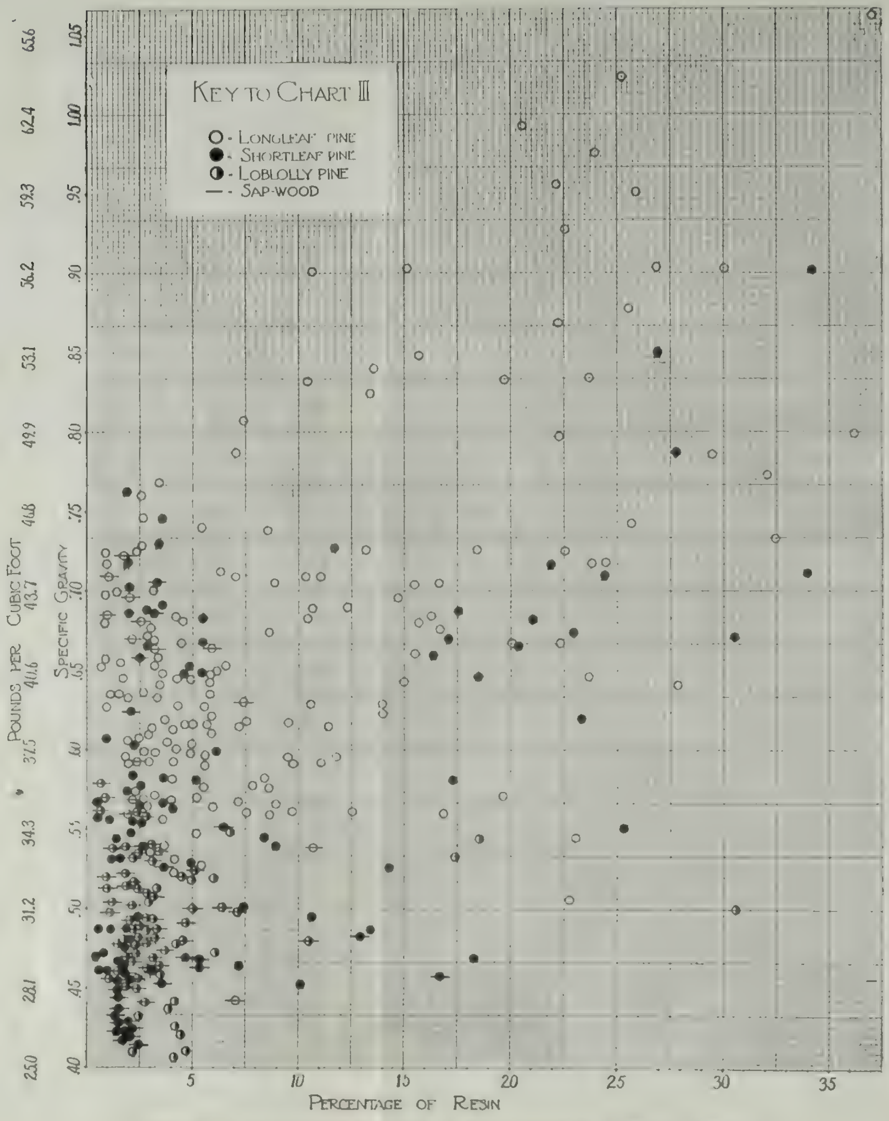

Chart III. Showing the Relation of Resin Content to Specific Gravity

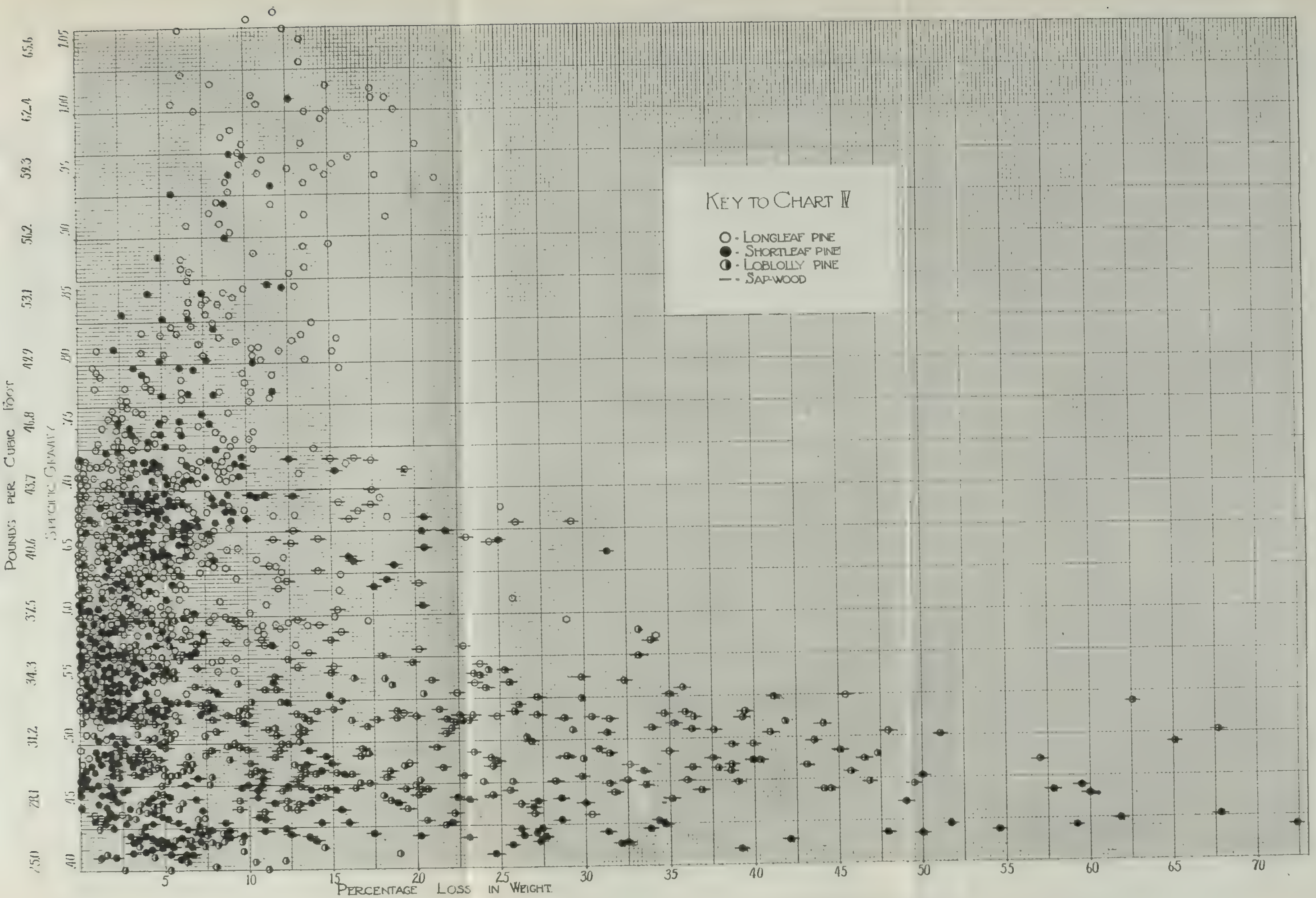

CHART IV. SHOWING THE RELATION OF SPECIFIC GRAVITY TO DECAY (WHERE THE PLOTTED POINTS REPRESENT THE INDIVIDUAL BLOCKS).

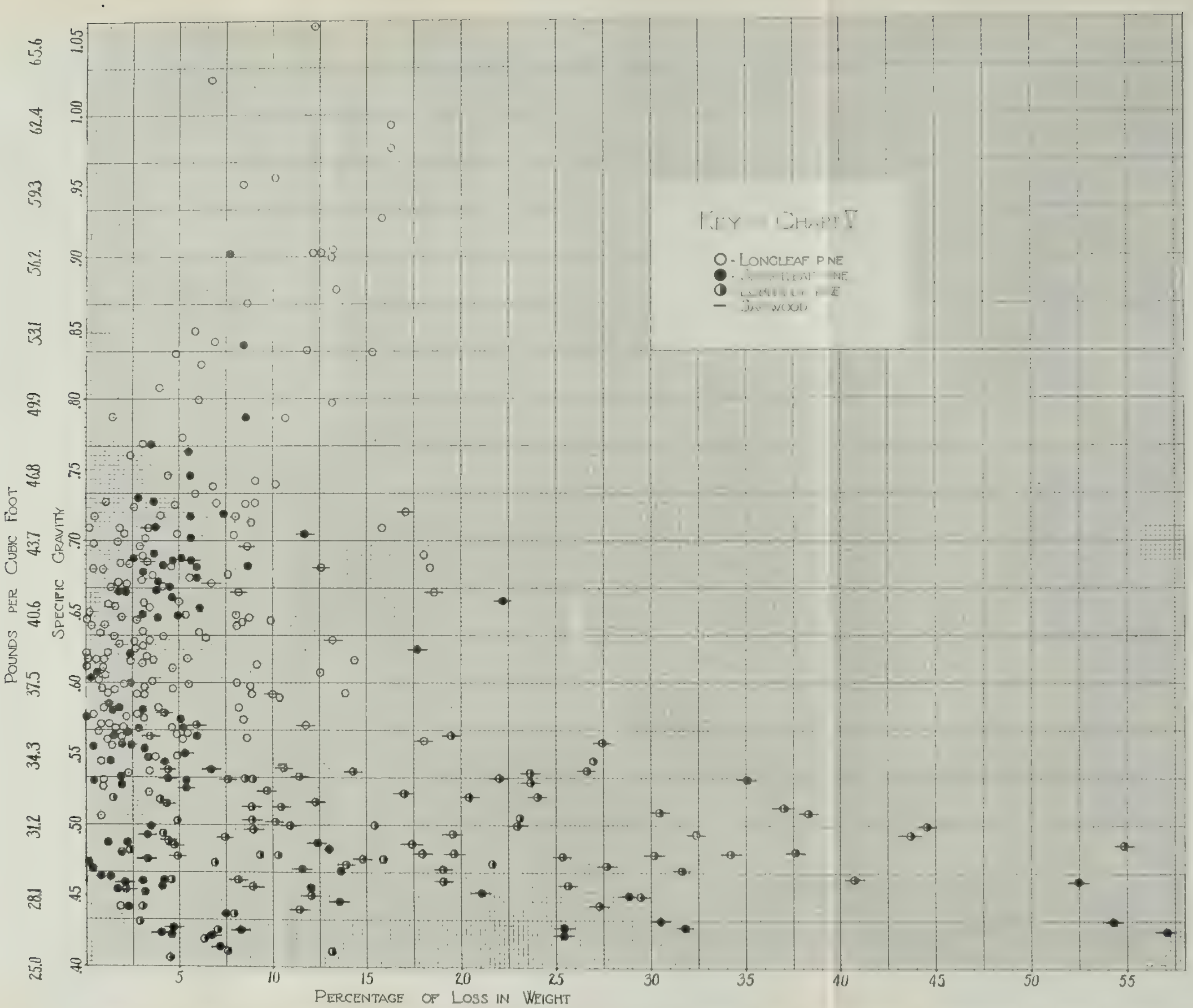

Chart V. Showing the Relation of Specific Gravity to Decay (Where the Plotted Points Represent the Averages for the Block Columns)

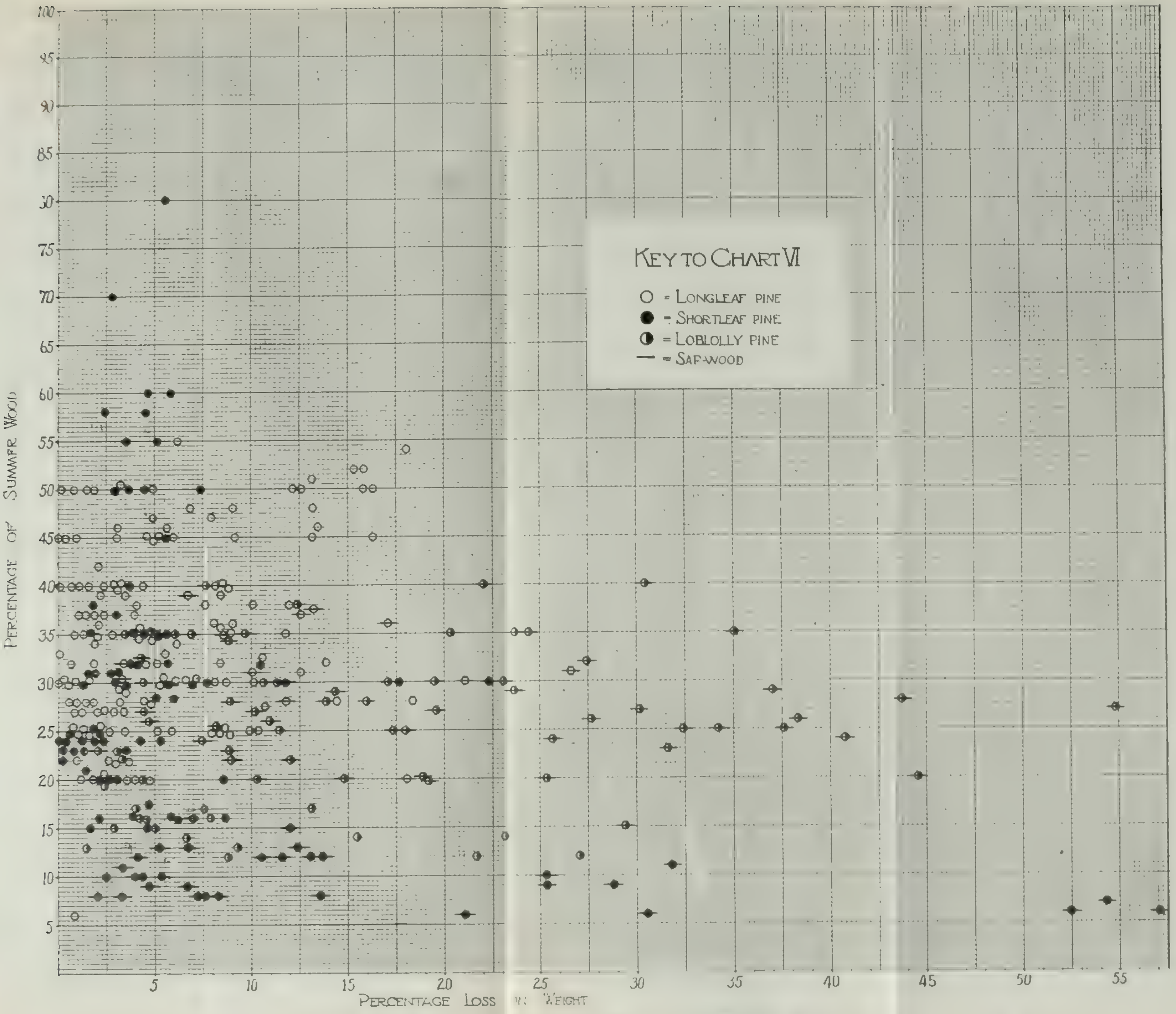

Chart VI.—Showing the Relation of Percentage of Summer Wood to Decay.

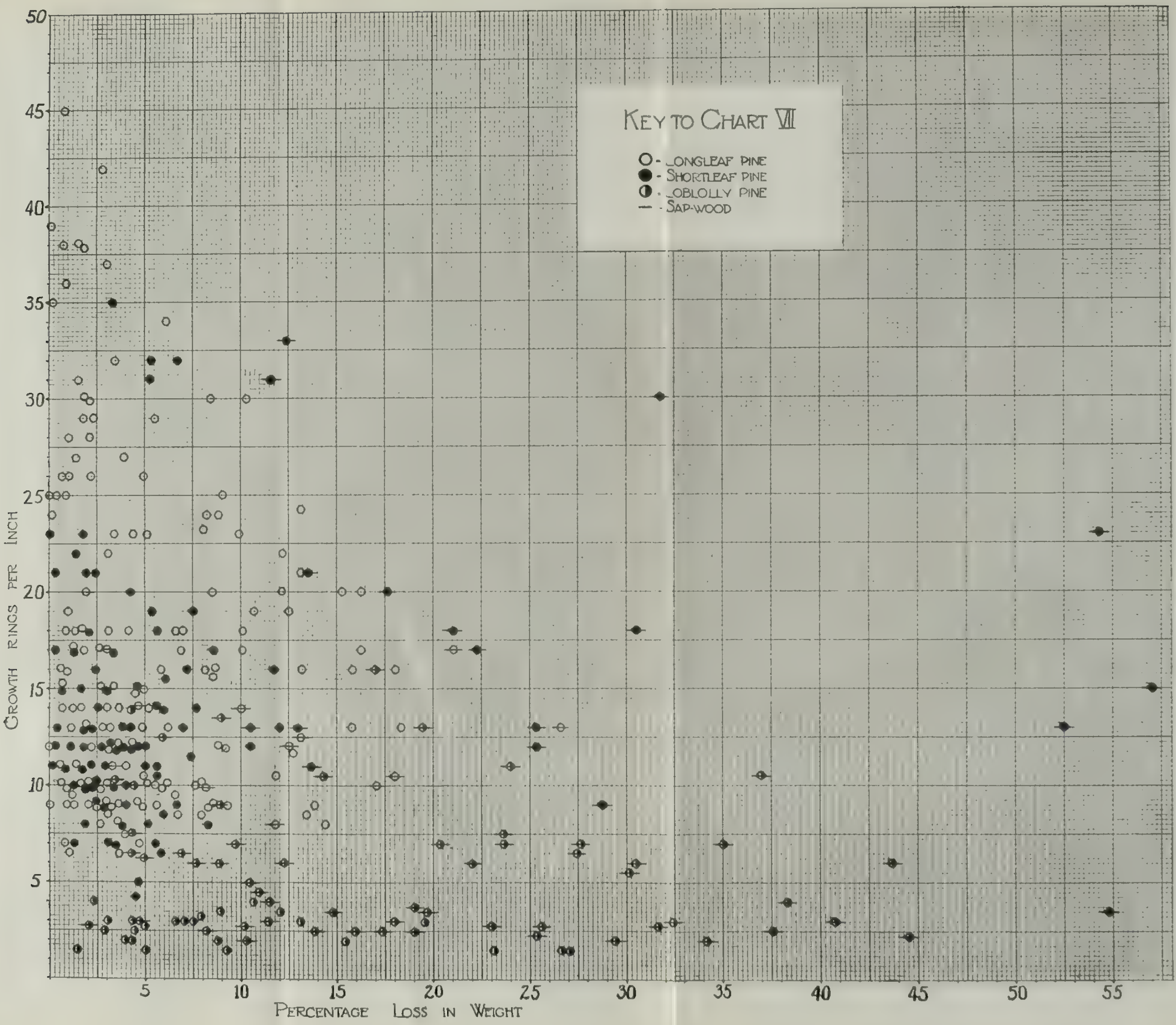

CHART VII. SHOWING THE RELATION OF NUMBER OF GROWTH RINGS PER INCH TO DECAY.

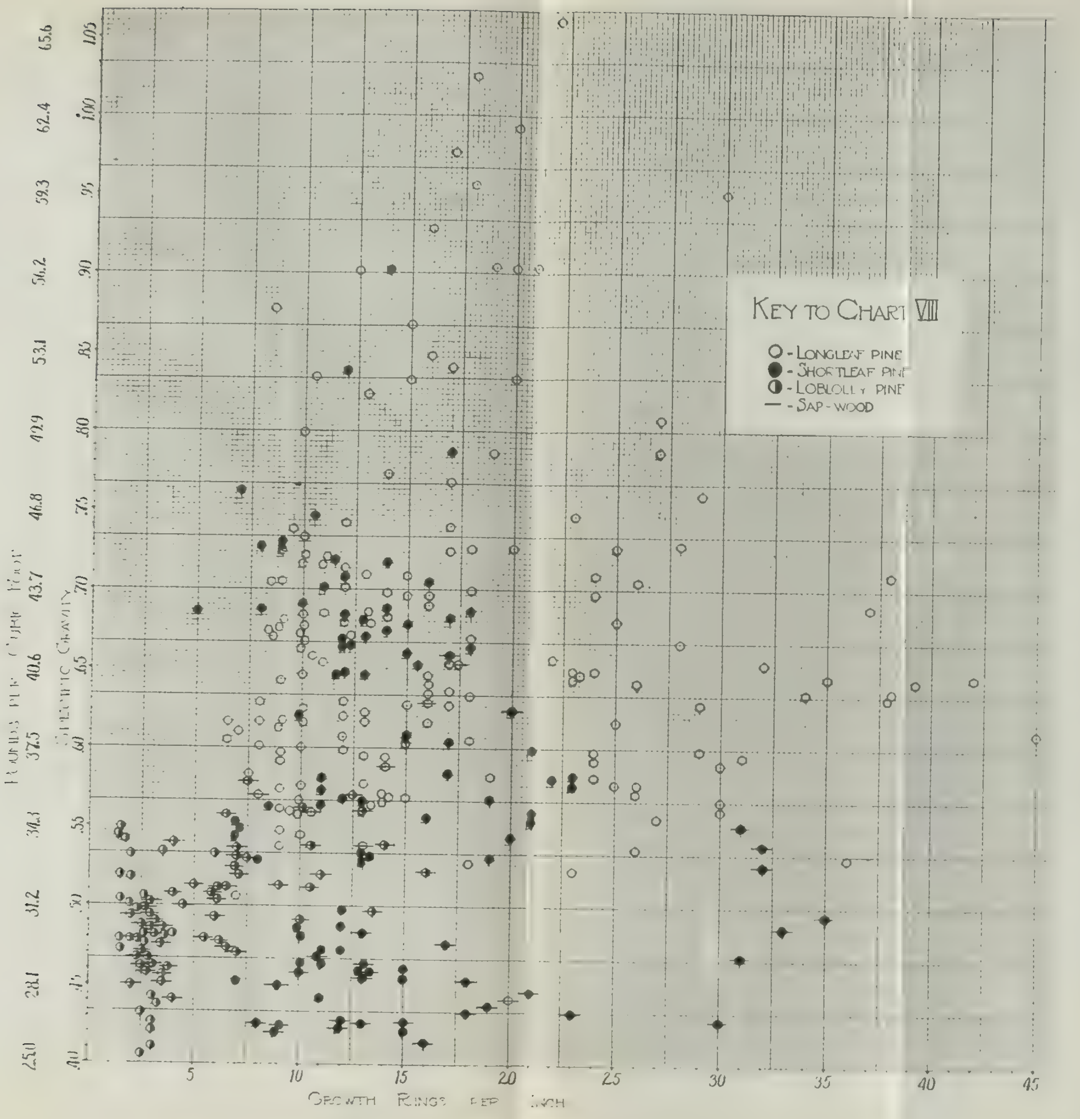

CHART VIII. SHOWING THE RELATION OF WIDTH OF THE GROWTH RINGS TO SPECIFIC GRAVITY

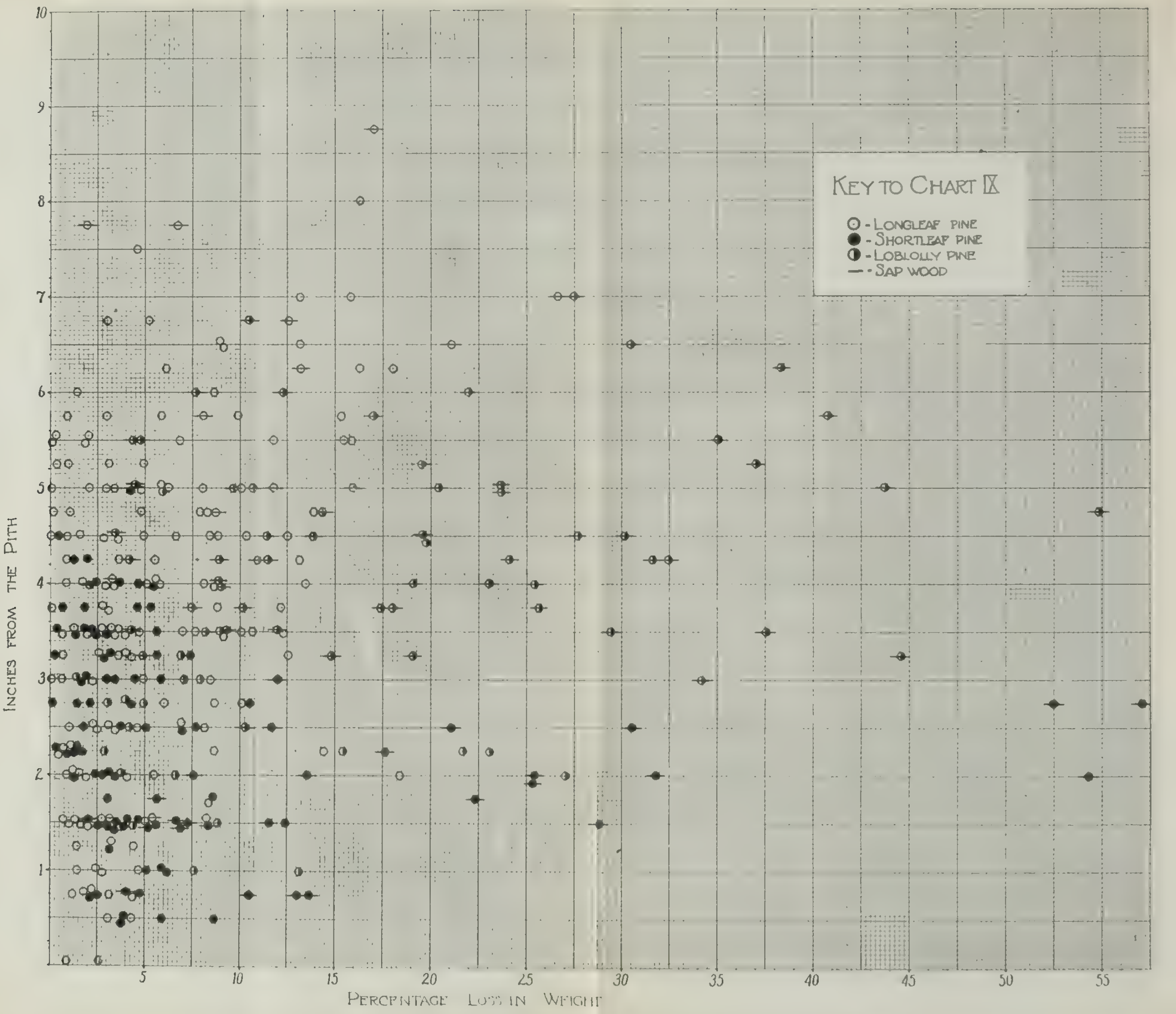

Chart IX. Showing the Relation of the Distance from the Pith to Decay

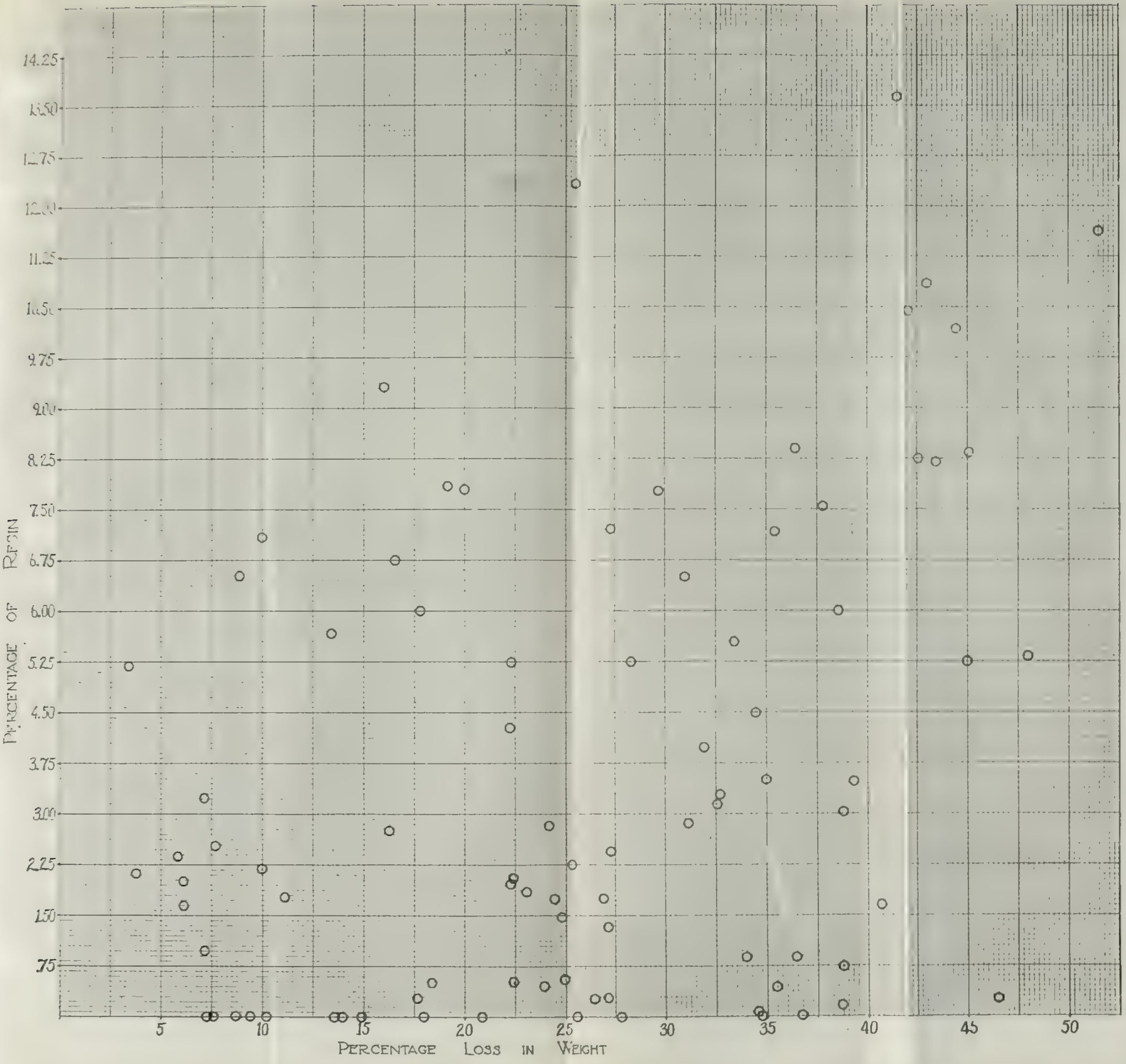

Chart X Showing the Influence of Pine Resin in Impregnated Yellow Poplar Wood on Its Decay Induced by *Lenzites sepiaria*

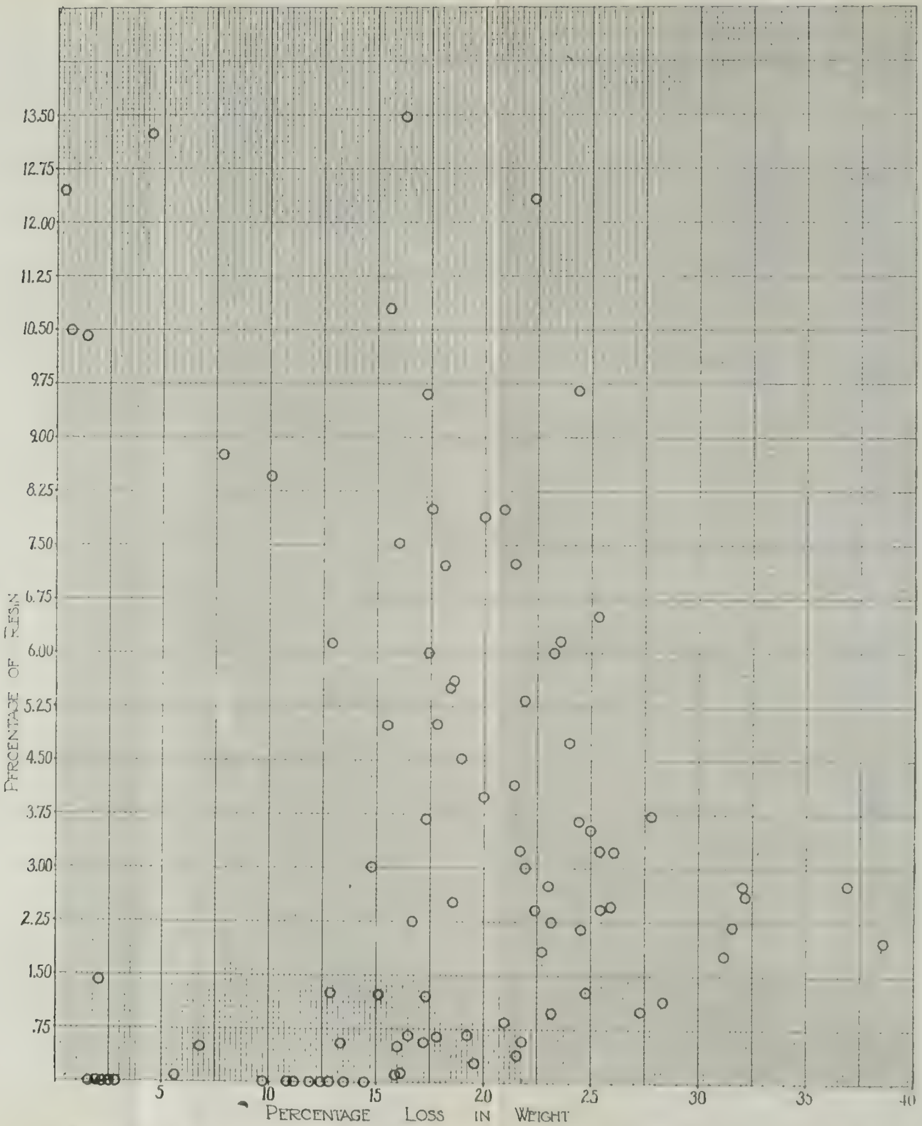

Chart XI. Showing the Influence of Pine Resin in Impregnated Yellow Poplar Wood on Its Decay Induced by *Polystictus hirsutus.*

BULLETIN

OF THE

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Vol. 19, No. 199 . . . . SEPTEMBER, 1917

Mill Inspections of Rail in 1915 and 1916

Rail Failure Statistics for 1916

Influence of Gage Length on Elongation in Drop Test of Rails

Tests of Manganese Steel Rails

By M. H. Wickhorst,
Engineer of Tests, Rail Committee

Discussion of "The Rail Failure Situation"

By C. W. Gennet, Jr.

Discussion of Impact Formula

By Gustav Lindenthal

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MILL INSPECTIONS OF RAIL IN 1915 AND 1916.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report gives the general results of the mill inspections of rail manufactured in 1915 and 1916 for some of the railroads represented on our Rail Committee and also gives some discussion of the specifications on which the rails were bought. The purpose is to determine what may be called the general characteristics of the rails made at the different mills as regards ductility, rejections, discard from the ingot, and No. 2 rails. First, the specifications will be considered and then will be given a tabulation of the results of mill inspections.

RAIL SPECIFICATIONS.

The specifications used by the various railroads were largely based upon the rail specifications of the American Railway Engineering Association. In some cases the A. R. E. A. specifications were used without change, but in most cases they were modified more or less. The rails reported on were all open hearth rails, no report of inspection of Bessemer rails having been received. The carbon requirements of the several specifications are listed in Table 1.

Table 1—Specified Carbons.

Railroad.	*Carbon Limits.*
A. R. E. A.	.62 to .75 for 85-lb. to 100-lb. rails.
A. T. & S. F.	.63 to .76 at Colorado, .62 to .75 at Gary for 90-lb. rail.
B. & O.	.62 to .75 for 90-lb. and 100-lb. rail.
C. R. I. & P.	.53 to .66 for 80-lb. rail, .62 to .75 for 100-lb. rail.
D. L. & W.	.64 to .77 for 91-lb., 101-lb. and 105-lb. rail.
Grand Trunk	.62 to .75 for 90-lb. and 100-lb. rail.
Ill. Cent.	.62 to .75 for 90-lb. rail.
N. & W.	.63 to .76 for 85-lb. and 100-lb. rail.
P. R. R. System	.60 to .75 for 100-lb. rail, .68 to .82 for 125-lb. rail, .68 to .87 for 130-lb. rail.
P. & R.	Mostly .67 to .80 for 90-lb. and 100-lb. rail, .68 to .82 for 130-lb. rail.

It will be noted that the carbon limits specified by most of the roads are the same or nearly the same as specified by the A. R. E. A., although there is some tendency to require higher carbon limits. The carbon (along with the other chemical elements) is usually determined from the ladle test, but one notable exception is the case of the Pennsylvania System

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that bought its 100-lb. rail on specifications requiring special analysis of the finished rail.

As a physical test, the drop test was used in all cases, it being usually required that the rail stand at least one blow of a 2,000-lb. tup from a given height, and usually also with a minimum elongation requirement of 6 per cent. Some of the features of the drop test requirements are mentioned below, as gathered from specifications submitted by some of the roads.

A. R. E. A.—Height of drop, 17 ft. for 80, 85 and 90-lb. rail, and 18 ft. for 100-lb. rail, tested preferably base upward. Minimum elongation, 6 per cent. or 5 per cent., in two consecutive inches. Two out of three pieces per heat must stand drop test. All pieces must be free from interior defect.

A. S. T. M.—Requirements similar to A. R. E. A., except that rails showing interior defects are accepted, but may be kept separate.

B. & O. System.—Requirements similar to A. R. E. A., but rails showing interior defect accepted as "specials."

D. L. & W. R. R.—Rails at the Lackawanna Steel Company were bought on A. R. E. A. specifications. At the Bethlehem Steel Company, the requirements were similar but the elongation was required to be 6 per cent. over a length of 6 inches instead of only 6 per cent. in the maximum inch, or what was originally one inch before stretching. At the Pennsylvania Steel Company the metal contained nickel and chromium and in lieu of the usual chemical requirements, the rails were required to meet certain minimum and maximum deflections in the drop test.

I. C. R. R.—For rails bought in the United States, the A. R. E. A. drop test requirements were used, except that the rails showing interior defects were accepted as "specials." For rails bought from the Algoma Steel Corporation, the requirements were similar, but in addition a "nick and break" test was made on rails representing each ingot.

N. & W. Ry.—Drop test requirements same as A. R. E. A.

P. R. R. System.—Height of drop, 18 ft. for 100, 125 and 130-lb. rails. All three pieces selected from each heat must stand test and be free from interior defect. Elongation required, 6 per cent. in one inch or 5 per cent. in two consecutive inches. In addition the 100-lb. rails were subjected to analysis of the finished rail and the carbon in the interor of the head near the web not allowed to exceed that in the corner of the head by more than 12 per cent.

P. & R. Ry.—Drop test requirements similar to A. R. E. A., except that rails showing interior defect were accepted as "specials."

RAIL INSPECTION RESULTS.

The results of the mill inspection of rails for 1915 and 1916 reported by the several roads are given in Table 3, being grouped by the mills at which the rails were rolled. There is shown for each lot, the top discard from the ingot, the amount of No. 2 rails, the elongation in the drop test and the amount of rejected rails. For each mill the total tonnages reported are given, and also the average percentages. In the case of the top discard and the elongation in the drop test, the average percentages are "weighted" averages, obtained by multiplying each percentage by the tons in the lot, thus obtaining "ton-percents." The total of the "ton-percents" is then divided by the total tons to obtain the average per cent.

In some cases the amount of No. 2 rails rolled was greater than the amount accepted. This does not, therefore, always show the rolling (including the total rolled) correctly in this respect and probably this feature should be changed in future reports.

The average results for each of the mills are collected together in Table 2. It is interesting to note that the average top discards at the several mills ranged from 10.0 per cent. to 28.7 per cent. with a general average of 17.9 per cent. The average elongation varied from 12.2 per cent. to 17.1 per cent. with a general average of 14.5 per cent. The average rejections ranged from 3.9 per cent. to 15.1 per cent. with a general average of 6.4 per cent. Of the total rejections, 42 per cent. were A rails. For more convenient presentation, Fig. 1 is given, showing some of the general results in diagrammatic form.

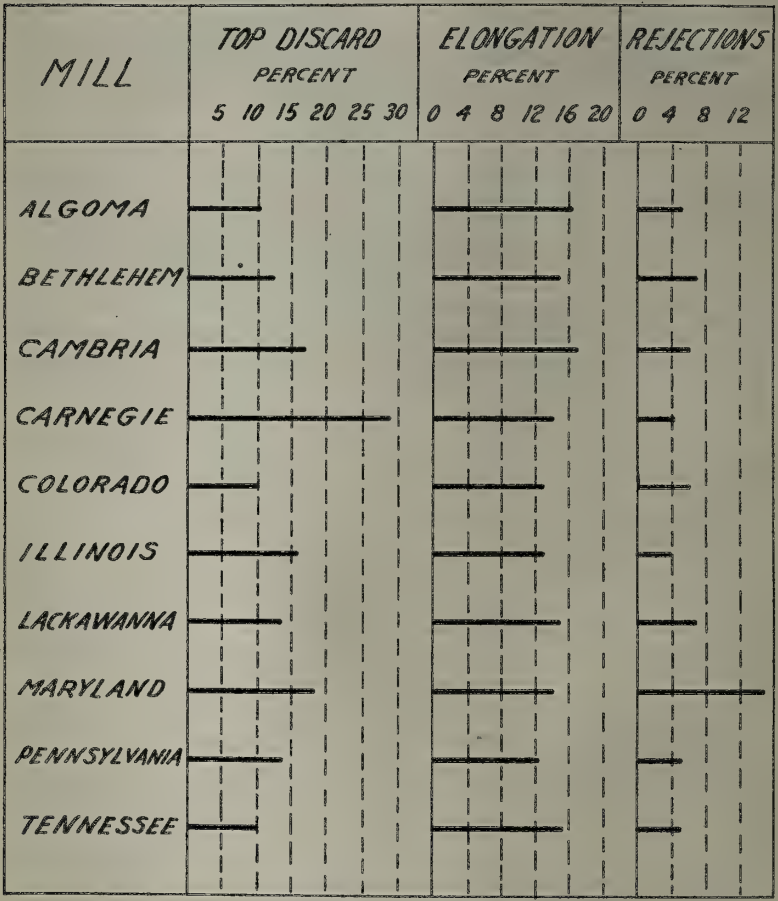

Fig. 1. Rails Inspected in 1915 and 1916.

TABLE 2—AVERAGE RESULTS OF MILL INSPECTIONS.

Mill	Av. Top Discard Per Cent.	ACCEPTED				Av. Elong. of Accepted Rails Per Cent.	REJECTED—Tons				Per Cent. of Total Tons Rejected			Total Tons Rolled	Per Cent. Rejected of Total Rolled
		No. 1 Tons	No. 2 Tons	Tota Tons	Per Cent. No. 2 of Total Accepted		Rails	Rails	Other Rails	Total	A Rails	B Rails	Other Rails		
Algoma	10.1	33,933	2,107	36,040	5.8	16.3	1,207	54	676	1,937	62	3	35	37,977	5.1
Bethlehem	12.3	49,427	1,848	51,275	3.0	15.2	2,282	622	1,103	4,007	57	15	28	55,282	7.2
Cambria	16.9	119,531	6,641	126,172	5.1	17.1	3,638	2,056	2,408	8,102	45	25	30	134,274	6.0
Carnegie	28.7	165,582	7,194	172,776	4.2	14.1	582	2,772	4,428	7,782	7	36	57	180,558	4.3
Colorado	10.0	43,095	2,186	45,281	4.8	13.0	1,248	331	1,364	2,943	42	11	47	48,224	6.1
Illinois	15.8	170,850	8,417	179,267	4.7	13.1	2,195	1,414	3,633	7,242	30	20	50	186,509	3.9
Lackawanna	13.2	44,204	1,508	45,712	3.3	15.2	1,620	864	853	3,337	48	26	26	49,049	6.8
Maryland	18.1	88,994	5,295	94,289	5.7	14.3	9,023	3,996	3,780	16,799	54	24	22	111,088	15.1
Pennsylvania	13.7	23,005	886	23,891	3.7	12.2	476	203	528	1,207	39	17	44	25,098	4.8
Tennessee	10.0	14,877	748	15,625	4.8	15.4	192	54	569	815	23	7	70	16,440	5.0
Total	17.9	753,498	36,830	790,328	4.9	14.5	22,463	12,366	19,342	54,171	42	23	35	844,499	6.4

TABLE 3—SUMMARY OF MILL INSPECTIONS OF RAIL

Railroad	Year Rolled	Specifications Used	Pounds Per Yard	Section	Specified Carbon		Av. Top Discard Per Cent.	ACCEPTED				Av. Elong. of Accepted Rails Per Cent.	REJECTED—Tons				Per Cent. of Total Tons Rejected			Total Tons Rolled	Per Cent. Rejected of Total Rolled
					Min.	Max.		No. 1 Tons	No. 2 Tons	Total Tons	Per Cent. No. 2 of Total Accepted		A Rails	B Rails	Other Rails	Total	A Rails	B Rails	Other Rails		
ALGOMA STEEL CORPORATION																					
G. T.	1915	A. R. E. A.	90	A. R. A.-A.	.62	.75	10.0	953	50	1,003	5.0	15.0	8	0	18	26	31	0	69	1,029	2.5
I. C.	1915	A. R. E. A., Mod.	90	A. R. A.-A.	.62	.75	10.5	27,165	2,016	29,181	6.9	16.7	894	25	548	1,467	61	2	37	30,648	4.8
"	1916	A. R. E. A., Mod.	90	A. R. A.-A.	.62	.75	8.0	5,815	41	5,856	0.7	14.8	305	29	110	444	69	6	25	6,300	7.0
				Total...	......	......	10.1	33,933	2,107	36,040	5.8	16.3	1,207	54	676	1,937	62	3	35	37,977	5.1
BETHLEHEM STEEL COMPANY																					
B. & O.	1916	163-1	100	A. R. A.-B.	.62	.75	14.7	3,497	168	3,665	4.6	13.2	25	0	22	47	53	0	47	3,712	1.2
D. L. & W.	1916	D. L. & W.	91	D. L. & W.	.64	.77	12.0	590	9	599	1.5	18.0	16	4	13	33	48	12	40	632	5.2
"	1915	"	101	"	.64	.77	14.0	3,186	29	3,215	0.9	14.0	167	33	43	243	69	14	17	3,458	7.0
"	1916	"	101	"	.64	.77	15.0	992	30	1,022	2.9	14.0	70	25	31	126	56	20	24	1,148	10.9
"	1915	"	105	"	.64	.77	12.0	3,492	206	3,698	5.5	11.0	87	22	62	171	51	13	36	3,869	4.4
"	1916	"	105	"	.64	.77	12.0	1,542	43	1,585	2.7	12.0	109	24	39	172	64	14	22	1,757	9.8
N. & W.	1915	N. & W.	100	A. R. A.-B.	.63	.76	12.5	4,866	165	5,031	3.3	14.7	105	0	80	185	57	0	43	5,216	3.6
"	1916	"	100	"	.63	.76	14.0	3,573	140	3,713	3.8	13.4	107	14	25	146	73	10	17	3,859	3.8
P. R. R.	1915	1915, 1st	100	P. S.	.60	.75	6.7	959	43	1,002	4.3	25.0	75	38	149	262	29	14	57	1,264	20.7
"	1915	1915, 2nd	100	"	.60	.75	6.7	955	47	1,002	4.7	23.0	41	11	42	94	44	12	44	1,096	8.6
"	1915	1915, 4th	100	"	.60	.75	12.5	4,955	133	5,088	2.6	23.0	287	87	244	618	46	14	40	5,706	10.8
"	1915	1915, 6th	125	"	.68	.82	11.5	2,769	135	2,904	4.6	16.0	367	96	44	507	72	19	9	3,411	14.7
"	1916	1915, P. S.	125	"	.68	.82	15.0	7,676	509	8,185	6.0	14.0	792	268	309	1,369	58	20	22	9,554	14.3
P. & R.	1915	A. S. T. M., Mod.	100	P. & R.	.63	.76	9.0	7,415	109	7,524	1.4	14.0	23	0	0	23	100	0	0	7,547	0.3
"	1916	"	100	"	.67	.80	9.0	2,960	82	3,042	2.6	14.0	11	0	0	11	100	0	0	3,053	0.3
				Total...	......	......	12.3	49,427	1,848	51,275	3.0	15.2	2,282	622	1,103	4,007	57	15	28	55,282	7.2

CAMBRIA STEEL CO.

B. & O.....	1915	163-1............	90	A. R. A.-A.	.62	.75	15.0	6,105	361	6,466	5.5	13.9	15	0	0	15	100	0	0	6,481	0.2
"	1916	"	90	"	.62	.75	13.8	14,203	681	14,884	4.6	14.1	5	0	223	228	2	0	98	15,112	1.5
"	1915	"	100	A. R. A.-B.	.62	.75	15.0	12,864	611	13,475	4.5	15.5	8	0	0	8	100	0	0	13,483	0.1
"	1916	"	100	"	.62	.75	15.0	12,380	800	13,180	6.1	14.4	16	17	83	116	14	15	71	13,296	0.9
"	1916	Vanadium.......	100	"	.62	.75	17.0	956	56	1,012	5.5	11.4	63	13	2	78	81	17	2	1,090	7.2
N. & W....	1915	N. & W.........	85	A. S. C. E.	.63	.76	13.0	1,462	77	1,539	5.0	16.6	17	0	7	24	71	0	29	1,563	1.5
"	1915	"	100	A. R. A.-B.	.63	.76	14.0	2,045	86	2,131	4.1	15.1	17	9	8	34	50	27	23	2,165	1.6
"	1916	"	100	"	.63	.76	17.0	3,508	178	3,686	4.9	16.4	178	76	341	595	30	13	57	4,281	14.0
P. R. R....	1915	1915, 1st.........	100	P. S.......	.60	.75	26.0	975	28	1,003	2.8	25.0	14	15	0	29	48	52	0	1,032	2.8
"	1915	1915, 2nd.........	100	"	.60	.75	26.0	952	50	1,002	5.0	27.0	29	9	0	38	76	24	0	1,040	3.7
"	1915	1915, 4th.........	100	"	.60	.75	24.5	21,304	1,127	22,431	5.0	26.0	418	1,141	786	2,345	18	49	33	24,776	9.5
"	1916	"	100	"	.60	.75	16.0	3,327	180	3,507	5.1	20.0	375	205	224	804	47	25	28	4,311	18.7
"	1915	1915, 6th.........	125	"	.68	.82	13.0	11,898	628	12,526	5.1	19.0	371	48	126	545	68	9	23	13,071	4.2
"	1916	1915, P. S.........	125	"	.68	.82	16.0	27,552	1,778	29,330	6.0	13.0	2,112	523	608	3,243	65	16	19	32,573	9.9
				Total...	......	......	16.9	119,531	6,641	126,172	5.1	17.1	3,638	2,056	2,408	8,102	45	25	30	134,274	6.0

CARNEGIE STEEL CO.

B. & O.....	1915	163-1............	90	A. R. A.-A.	.62	.75	24.0	1,894	73	1,967	3.7	11.2	0	0	0	0	0	0	0	1,967	0.0
"	1915	"	90	A. R. A.-B.	.62	.75	23.0	66	0	66	0.0	11.5	0	0	0	0	0	0	0	66	0.0
"	1916	"	90	A. R. A.-A.	.62	.75	23.0	7,537	201	7,738	2.6	13.3	0	38	3	41	0	93	7	7,779	0.5
"	1915	"	100	"	.62	.75	29.0	1,850	98	1,948	5.0	9.9	0	30	15	45	0	67	33	1,993	2.3
"	1915	"	100	A. R. A.-B.	.62	.75	28.0	9,715	461	10,176	4.5	12.4	0	0	0	0	0	0	0	10,176	0.0
"	1916	"	100	A. R. A.-A.	.62	.75	29.0	8,956	198	9,154	2.2	8.9	0	0	0	0	0	0	0	9,154	0.0
"	1916	"	100	A. R. A.-B.	.62	.75	29.4	18,050	570	18,620	3.1	11.5	0	58	109	167	0	35	65	18,787	0.9
N. & W....	1915	N. & W.........	85	A. S. C. E.	.63	.76	25.0	1,061	21	1,082	1.9	14.9	0	0	0	0	0	0	0	1,082	0.0
"	1915	"	100	A. R. A.-B.	.63	.76	28.5	14,025	589	14,614	4.0	14.7	177	0	100	277	64	0	36	14,891	1.8
"	1916	"	85	A. S. C. E.	.63	.76	25.0	484	16	500	3.2	13.3	0	0	0	0	0	0	0	500	0.0
"	1916	"	100	A. R. A.-B.	.63	.76	28.5	13,744	699	14,443	4.8	12.3	405	29	20	454	89	6	5	14,897	3.1
P. R. R....	1915	1915, 1st.........	100	P. S.......	.60	.75	25.9	949	50	999	5.0	24.0	0	40	74	114	0	35	65	1,113	10.0
"	1915	1915, 2nd.........	100	"	.60	.75	25.9	976	26	1,002	2.5	25.0	0	22	64	86	0	26	74	1,088	7.9
"	1915	1915, P. S.......	130	"	.68	.87	27.0	6,341	335	6,676	5.0	16.0	0	117	38	155	0	75	25	6,831	2.3
"	1916	"	130	"	.68	.87	27.0	6,648	349	6,997	5.0	13.0	0	458	147	605	0	76	24	7,602	7.9
Pa. L. W. P.	1915	1915, 4th.........	100	"	.60	.75	32.5	31,014	1,545	32,559	4.8	16.5	0	1,000	1,987	2,987	0	34	66	35,546	8.4
"	1916	"	100	"	.60	.75	28.0	33,816	1,596	35,412	4.5	14.9	0	980	1,871	2,851	0	34	66	38,263	7.4
P. & R.....	1915	A. S. T. M., Mod.	90	A. S. C. E.	.64	.77	27.5	2,306	114	2,420	4.9	14.0	0	0	0	0	0	0	0	2,420	0.0
"	1916	"	90	"	.67	.80	27.5	2,039	56	2,095	2.6	14.0	0	0	0	0	0	0	0	2,095	0.0
"	1916	"	100	P. & R....	.67	.80	27.5	2,061	99	2,160	4.5	12.0	0	0	0	0	0	0	0	2,160	0.0
"	1916	P. R. R.........	130	P. S.......	.68	.82	27.5	2,050	98	2,148	4.5	13.0	0	0	0	0	0	0	0	2,148	0.0
				Total...	......	......	28.7	165,582	7,194	172,776	4.2	14.1	582	2,772	4,428	7,782	7	36	57	180,558	4.3

TABLE 3—SUMMARY OF MILL INSPECTIONS OF RAIL—Continued

Railroad	Year Rolled	Specifications Used	Pounds Per Yard	Section	Specified Carbon		Av. Top Discard Per Cent.	ACCEPTED				Av. Elong. of Accepted Rails Per Cent.	REJECTED—Tons				Per Cent. of Total Tons Rejected			Total Tons Rolled	Per Cent. Rejected of Total Rolled
					Min.	Max.		No. 1 Tons	No. 2 Tons	Total Tons	Per Cent. No. 2 of Total Accepted		A Rails	B Rails	Other Rails	Total	A Rails	B Rails	Other Rails		
COLORADO FUEL & IRON CO.																					
A. T. & S. F.	1916	A. R. E. A., Mod.	90	S. F.......	.63	.76	10.0	43,095	2,186	45,281	4.8	13.0	1,248	331	1,364	2,943	42	11	47	48,224	6.1
ILLINOIS STEEL CO., GARY WORKS																					
A. T. & S. F.	1916	A. R. E. A., Mod.	90	S. F.......	.62	.75	10.0	11,274	610	11,884	5.1	20.0	191	0	125	316	60	0	40	12,200	2.6
B. & O....	1915	163-1............	80	A. S. C. E.	.53	.66	8.0	1,900	42	1,942	2.2	17.9	0	0	11	11	0	0	100	1,953	0.5
"	1915	163-1............	90	A. R. A.-A.	.62	.75	11.0	2,201	102	2,303	4.4	12.3	0	0	0	0	0	0	0	2,303	0.0
"	1916	163-1............	90	"	.62	.75	9.5	2,102	95	2,197	4.3	12.2	3	0	13	16	19	0	81	2,213	0.7
"	1915	163-1............	100	"	.62	.75	9.5	3,369	184	3,553	5.2	10.6	0	0	0	0	0	0	0	3,553	0.0
"	1916	163-1............	100	"	.62	.75	9.8	9,843	351	10,194	3.4	12.0	36	0	50	86	42	0	58	10,280	0.8
"	1916	163-1............	100	A. R. A.-B.	.62	.75	7.5	840	128	968	1.3	11.1	12	0	3	15	80	0	20	983	1.5
C. R. I. & P.	1916	I. S. Co.........	80	A. S. C. E.	.53	.66	10.0	18	0	18	0.0	8.0	0	0	0	0	0	0	0	18	0.0
"	1916	A. R. E. A.......	90	A. R. A.-A.	.62	.75	12.0	10,744	505	11,249	4.4	12.0	211	0	82	293	72	0	28	11,542	2.3
"	1916	"	100	"	.62	.75	12.0	30,423	1,398	31,821	4.3	11.0	1,278	26	196	1,500	85	2	13	33,321	4.5
G. T.......	1915	"	90	"	.62	.75	10.0	1,344	71	1,415	5.0	13.0	76	0	9	85	89	0	11	1,500	5.7
"	1915	"	100	"	.62	.75	10.0	4,593	250	4,843	5.1	12.0	157	0	56	213	74	0	26	5,056	4.2
"	1916	"	90	"	.62	.75	10.0	3,803	201	4,004	5.0	14.0	21	0	13	34	62	0	38	4,038	0.8
"	1916	"	100	"	.62	.75	10.0	6,017	293	6,310	4.7	12.0	151	0	52	203	74	0	26	6,513	3.1
I. C........	1915	A. R. E. A., Mod.	90	"	.62	.75	10.0	10,338	682	11,020	6.2	12.2	0	0	48	48	0	0	100	11,068	0.4
"	1916	"	90	"	.62	.75	10.0	9,765	386	10,151	3.8	9.8	59	19	113	191	31	10	59	10,342	1.8
Pa. L. W. P.	1916	1915, 4th.........	100	P. S.......	.60	.75	23.0	32,191	1,617	33,808	4.8	15.6	0	1,247	1,973	3,220	0	39	61	37,028	8.7
"	1916	1915, 4th.........	100	"	.60	.75	25.0	30,085	1,502	31,587	4.8	12.4	0	122	889	1,011	0	12	88	32,598	3.1
				Total...	......	......	15.8	170,850	8,417	179,267	4.7	13.1	2,195	1,414	3,633	7,242	30	20	50	186,509	3.9

LACKAWANNA STEEL CO.

D. L. & W..	1915	A. R. E. A......	91	D. L. & W.	.64	.77	9.0	2,023	55	2,078	2.6	16.0	38	6	13	57	67	10	23	2,135	2.7
"	1915	"	101	"	.64	.77	11.0	311	8	319	2.5	13.0	43	0	2	45	93	0	7	364	12.4
"	1915	"	105	"	.64	.77	11.0	7,910	173	8,083	2.1	12.0	211	22	44	277	76	8	16	8,360	3.3
"	1916	"	105	"	.64	.77	9.5	9,930	220	10,150	2.2	11.0	289	73	93	455	63	16	21	10,605	4.3
G. T.......	1915	"	90	A. R. A.-A	.62	.75	9.8	1,345	73	1,418	5.1	14.0	21	0	18	39	54	0	46	1,457	2.6
N. & W.....	1915	N. & W..........	100	A. R. A.-B.	.63	.76	10.0	1,011	15	1,026	1.4	16.2	22	0	5	27	82	0	18	1,053	2.5
"	1916	"	100	"	.63	.76	9.0	963	21	984	2.1	13.1	59	0	15	74	80	0	20	1,058	6.9
P. R. R....	1915	1915, 1st..........	100	P. S.......	.60	.75	25.0	1,005	7	1,012	0.7	26.0	0	50	85	135	0	37	63	1,147	11.8
"	1915	1915, 2nd.........	100	"	.60	.75	25.0	972	2	974	0.2	23.0	0	9	0	9	0	100	0	983	0.9
"	1915	1915, 4th..........	100	"	.60	.75	30.0	4,896	258	5,154	5.0	23.0	0	556	379	935	0	59	41	6,089	15.3
"	1915	1915, 6th..........	125	"	.68	.82	12.5	2,677	145	2,822	5.1	15.0	207	0	73	280	74	0	26	3,102	8.9
"	1916	1915, P. S.........	125	"	.68	.82	10.4	9,661	490	10,151	4.8	16.0	730	148	120	998	73	15	12	11,149	8.9
P. & R......	1915	A. S. T. M., Mod.	90	A. S. C. E.	.67	.80	.80	1,500	41	1,541	2.6	16.0	0	0	6	6	0	0	100	1,547	0.4
				Total...	......	......	13.2	44,204	1,508	45,712	3.3	15.2	1,620	864	853	3,337	48	26	26	49,049	6.8

MARYLAND STEEL CO.

B. & O.....	1915	163–1.............	100	A. R. A.-B.	.62	.75	15.0	4,153	193	4,346	4.4	13.3	69	11	34	114	60	10	30	4,460	2.6
"	1916	"	100	"	.62	.75	13.8	8,190	463	8,653	5.4	7.9	233	59	181	473	49	12	39	9,126	5.8
N. & W....	1915	N. & W.........	85	A. S. C. E.	.63	.76	13.0	2,702	136	2,838	4.8	13.2	146	28	73	247	59	11	30	3,085	8.0
"	1915	"	100	A. R. A.-B.	.63	.76	13.5	3,356	129	3,485	3.7	12.3	133	19	33	185	72	10	18	3,670	5.0
"	1916	"	100	"	.63	.76	13.4	4,001	89	4,090	2.2	9.1	349	99	123	571	61	17	22	4,661	12.3
P. R. R....	1915	1915, 4th........	100	P. S.......	.60	.75	27.1	14,400	1,508	15,908	9.5	22.0	0	1,772	1,510	3,282	0	54	46	19,190	17.
"	1915	1915, 6th........	125	"	.68	.82	15.7	10,891	542	11,433	4.8	20.0	1,724	248	230	2,202	78	11	11	13,635	16.2
"	1916	1915, P. S.......	125	"	.68	.82	18.0	38,449	2,169	40,618	5.3	12.0	6,205	1,749	1,596	9,550	65	18	17	50,168	19.0
P. & R......	1916	A. S. T. M., Mod.	100	P. & R....	.67	.80	8.0	2,852	66	2,918	2.4	9.0	164	11	0	175	94	6	0	3,093	5.7
				Total...	......	......	18.1	88,994	5,295	94,289	5.7	14.3	9,023	3,996	3,780	16,799	54	24	22	111,088	15.1

TABLE 3—SUMMARY OF MILL INSPECTIONS OF RAIL—Concluded

Railroad	Year Rolled	Specifications Used	Pounds Per Yard	Section	Specified Carbon		Av. Top Discard Per Cent.	ACCEPTED				Av. Elong. of Accepted Rails Per Cent.	REJECTED—Tons				Per Cent. of Total Tons Rejected			Total Tons Rolled	Per Cent. Rejected of Total Rolled
					Min.	Max.		No. 1 Tons	No. 2 Tons	Total Tons	Per Cent. No. 2 of Total Accepted		A Rails	B Rails	Other Rails	Total	A Rails	B Rails	Other Rails		
PENNSYLVANIA STEEL CO.																					
D. L. & W..	1915	D. L. & W......	105	D. L. & W.	......	......	15.0	5,953	208	6,161	4.5	12.0	156	10	22	188	83	5	12	6,349	2.9
"	1916	"	105	"	......	......	14.0	2,773	290	3,063	9.5	12.0	108	33	109	250	43	13	44	3,313	7.6
P. R. R....	1915	1915, 1st.........	100	P. S.......	.60	.75	18.4	934	51	985	5.2	17.0	111	111	222	444	25	25	50	1,429	29.4
"	1915	1915, 2nd........	100	"	.60	.75	18.4	968	50	1,018	4.9	16.0	49	49	97	195	25	25	50	1,213	15.6
P. & R.....	1915	A. S. T. M., Mod.	90	A. S. C. E.	.67	.80	12.0	2,606	46	2,652	1.7	12.0	11	0	38	49	22	0	78	2,701	1.8
"	1915	"	100	P. & R....	.67	.80	12.0	5,256	131	5,387	2.4	11.0	19	0	40	59	32	0	68	5,446	1.1
"	1916	"	100	"	.67	.80	12.0	4,515	110	4,625	2.3	12.0	22	0	0	22	100	0	0	4,647	0.4
				Total...	......	......	13.7	23,005	886	23,891	3.7	12.2	47[illegible]	203	528	1,207	39	17	44	25,098	4.8
TENNESSEE COAL, IRON & R. R. CO.																					
I. C........	1916	A. R. E. A., Mod.	90	A. R. A. A.	.62	.75	10.0	14,877	748	15,625	4.8	15.4	192	54	569	815	23	7	70	16,440	5.0

RAIL FAILURE STATISTICS FOR 1916.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report deals with the statistics of rail failures collected for the year ending October 31, 1916, furnished by the railroads of the United States and Canada in response to a circular sent out by the American Railway Association. The information furnished by each railroad showed the number of tons laid of each year's rolling from each mill, the equivalent number of track miles, and the total number of failures that occurred in each year's rolling from the date laid until October 31, 1916.

The failures were divided into four classes, namely, head, web, base and "broken." They were reported by the railroads on American Railway Engineering Association form 408 as revised in 1915. (See Manual for 1915, page 104.) The reports cover rollings for 1911 and succeeding years and the ages of the rollings would average in the track about the years shown below:

1911	5 years
1912	4 years
1913	3 years
1914	2 years
1915	1 year
1916	Several months

The tonnages represented by the statistics in this report are shown below:

Year Rolled	Bessemer	Open-Hearth	Total
1911	305,910	810,396	1,116,306
1912	203,702	1,254,960	1,458,662
1913	135,870	1,503,366	1,639,236
1914	63,599	1,026,915	1,090,514
1915	12,212	1,080,361	1,092,573
1916	33,658	749,765	783,423

The equivalent track miles are as follows:

Year Rolled	Bessemer	Open-Hearth	Total
1911	2,198.87	5,770.54	7,969.41
1912	1,448.22	8,812.71	10,260.93
1913	969.97	10,365.44	11,335.41
1914	452.49	7,052.75	7,505.24
1915	90.29	7,291.00	7,381.29
1916	259.67	5,093.04	5,352.71

It will be noted that in recent years the Bessemer steel has formed only a small part of the rail rolled as covered by the returns in this report. The failures were tabulated with reference particularly to the performance of the rails made by the different mills and were classified successively in the following order: Kind of steel (Bessemer or Open-

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Rail Report 65, July, 1917.

Hearth), mill, year rolled, weight per yard, section and railroad. The totals were figured for the groups by the year rolled.

Lots of less than 1,000 tons (that is, less than 1,000 tons in any one year's rolling for a railroad) were excluded from the tabulation, as they would unnecessarily extend the tables and not materially change the group totals and averages. The method of compiling the statistics was to make prints (generally blue-line whiteprints) of the reports submitted by the different railroads, after seeing that all the lines were fully filled out, and then cutting them up along the horizontal lines with a large card cutter or trimming board. The strips constituted the units in the tables, and after sorting in suitable order and collecting into the desired groups, the information was transcribed on a typewriter into tables, from which zinc plates were made for printing in the report.

FAILURES CLASSIFIED BY MILLS.

The detail tabulations by mills and years rolled are given in Table 7, sheets 1 to 20 inclusive. A condensed table showing the failures of each year's rolling of each mill is given as Table 1. First it is interesting to note from this table the comparative performance of Bessemer and Open-Hearth rails. Figuring the failures per 100 track miles of Open-Hearth rails as 100 for each of the years 1911, 1912, 1913 and 1914, the relative failures of the Bessemer rails, together with the failures per 100 track miles, are shown below:

FAILURES OF OPEN-HEARTH AND BESSEMER COMPARED.

Year Rolled	Years Service	Failures per 100 Track Miles Open-Hearth	Failures per 100 Track Miles Bessemer	Comparative Failures Open-Hearth	Comparative Failures Bessemer
1911............	5	161.9	214.1	100	132
1912............	4	74.2	107.7	100	145
1913............	3	43.3	60.1	100	135
1914............	2	18.9	32.3	100	171

It will be noted that the failures of Bessemer rails per 100 track miles were considerably greater than those of the Open-Hearth rails. It is probably also true that the Open-Hearth rails were, in general, in more severe service, so that the actual difference under the same conditions may have been greater.

The comparison between Open-Hearth and Bessemer rails as obtained from the statistics in the 1913, 1914 and 1915 reports and this report are collected together below:

BESSEMER FAILURES COMPARED WITH OPEN-HEARTH FAILURES TAKEN AS 100.

Year	Years' Service			
Rolled	2	3	4	5
1908.................	..	..	..	112
1909.................	..	..	195	188
1910.................	..	230	207	154
1911.................	249	291	155	132
1912.................	219	143	145	..
1913.................	142	135	..	..
1914.................	171	..	..	..

These figures indicate that the failures of Bessemer rails occur at a considerably higher rate than the failures of Open-Hearth rails in their early period of service, but as they remain longer in track, the rates of failure become nearer alike.

The failures per 100 track miles for each of the mills classified by kind of steel and year rolled, are shown graphically in Fig. 1.

The average weights per yard, compiled from the tonnages used in this report, are shown in Table 6. It will be noted that the Bessemer rail tends to become lighter in weight and the Open-Hearth to become heavier, due presumably to replacement of Bessemer rail for the more important service by Open-Hearth rail.

The results shown in these statistics are in general consistent among themselves, but inconsistencies occur in the comparison of some of the rollings from year to year due to differences in the railroads that have reported on such rollings from year to year. Since these statistics were first started they have yearly become more complete by more roads sending in reports and by the reports being made out in better form. But also in a small number of cases roads have failed to make reports on rollings that had previously been reported on. In this way the rails shown for any year's rolling by a mill may not be the same rails that had been previously reported on. Thus it may happen that the failures per 100 track miles in a group may show less than had been shown in a previous report for the same group for a less period of service. Although the general trend of the rail failures is probably satisfactorily shown, it is necessary for the above reasons to exercise care in using the smaller groupings.

RANKING OF MILLS.

In order to show more conveniently the relative number of failures from each of the mills and to show the ranking of the mills as regards the failure performance of the rails rolled by them, Table 3 has been prepared. Taking the average number of failures per 100 track miles of all the mills in each group (Bessemer and Open-Hearth), in any year's rolling as 100, the relative number of failures of each of the mills is shown for the years 1911, 1912, 1913 and 1914. The later rollings are not included because of being too young. The rank of each mill is also shown for each year's rolling. It is interesting and gratifying to note from the tables and diagram that the mills which had the greatest number of failures some years ago and ranked the lowest are showing a tendency to a considerable reduction in the number of failures and ranking well in more recent years.

COMPARISON WITH PREVIOUS YEARS.

One important purpose of these statistics is to enable comparisons to be made of the performance of rail rolled from year to year, and Tables 4 and 5 are given showing the general records for the years 1913, 1914,

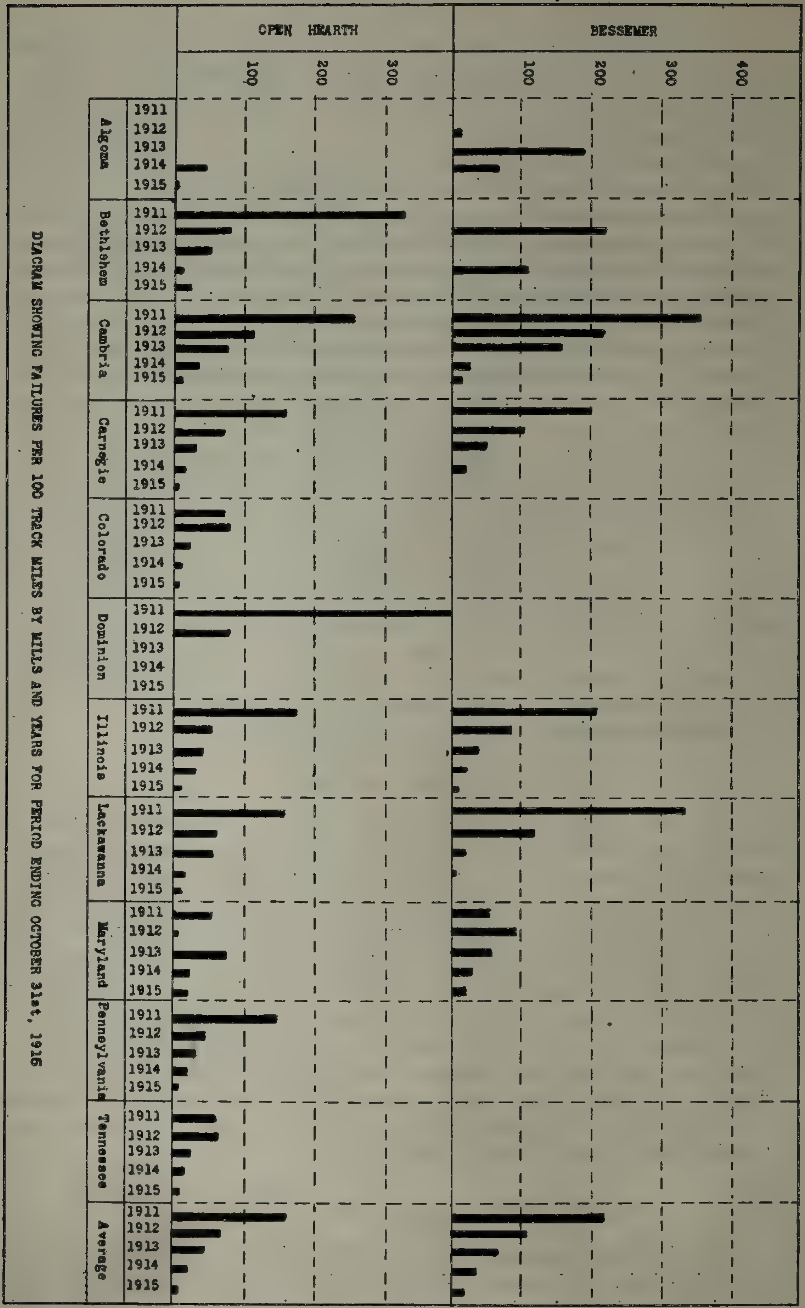
DIAGRAM SHOWING FAILURES PER 100 TRACK MILES BY MILLS AND YEARS FOR PERIOD ENDING OCTOBER 31st, 1916
OPEN HEARTH
BESSEMER
100
200
300
100
200
300
400
Algoma
Bethlehem
Cambria
Carnegie
Colorado
Dominion
Illinois
Lackawanna
Maryland
Pennsylvania
Tennessee
Average
1911
1912
1913
1914
1915

FIG. 1.

1915 and 1916, one table for Bessemer rails and the other for Open-Hearth rails. The final comparison is made on the basis of five years' service, but before closing the record of any year's rolling, a comparison can be made on the performance of a less number of years' service. The records are closed for the 1908, 1909, 1910 and 1911 rollings and it will be noted that the average of the Bessemer rail from all the mills showed reductions in the number of failures in the successive years. The 1911 Open-Hearth rail, however, showed a somewhat larger number of failures per 100 track miles than did the 1910 rail, although less than the 1908 and 1909 rail. Judging from the record of the 1912 rail to date it promises to do considerably better than previous rollings. Taking the total of both Bessemer and Open-Hearth, the 1911 rail shows a lower number of failures than previous rollings.

A summary of the general results as given in the reports for 1913, 1914, 1915 and in this report is given herewith as Table 2. The average failures per 100 track miles of the rollings for the several years, including both Bessemer and Open-Hearth rails, is given in the following table:

Year	Years Service					
Rolled	0	1	2	3	4	5
1908	..	..	..	..	..	398.1
1909	..	..	..	..	224.1	277.8
1910	..	..	..	124.0	152.7	198.5
1911	..	..	77.0	104.4	133.3	176.3
1912	..	28.9	32.1	49.3	78.9	..
1913	2.0	12.5	25.8	44.8	..	..
1914	1.2	8.2	19.8	..	..	..
1915	0.7	8.9	..	..	..	..
1916	1.6	..	..	..	..	..

These results are also shown diagrammatically in Fig. 2. It will be noted that the 1908, 1909, 1910 and 1911 rollings show successively decreased numbers of failures compared on a basis of five years' service and the later rollings also show successive reductions in failures when compared on a less number of years' service. This information is also presented in different form in Fig. 3.

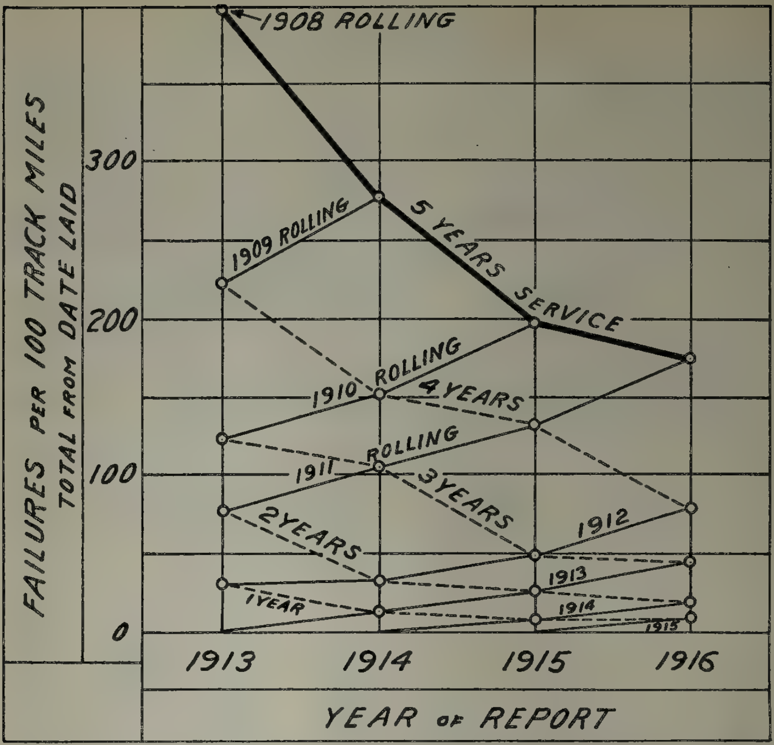

Fig. 2.—The Heavy Solid Line Shows the Failures After Five Years' Service for the 1908, 1909, 1910 and 1911 Rollings. The Dotted Lines Show the Failures for Less Years' Service. The Light Solid Lines Show the Accumulated Failures for Successive Years, Each Line Representing a Certain Year's Rolling.

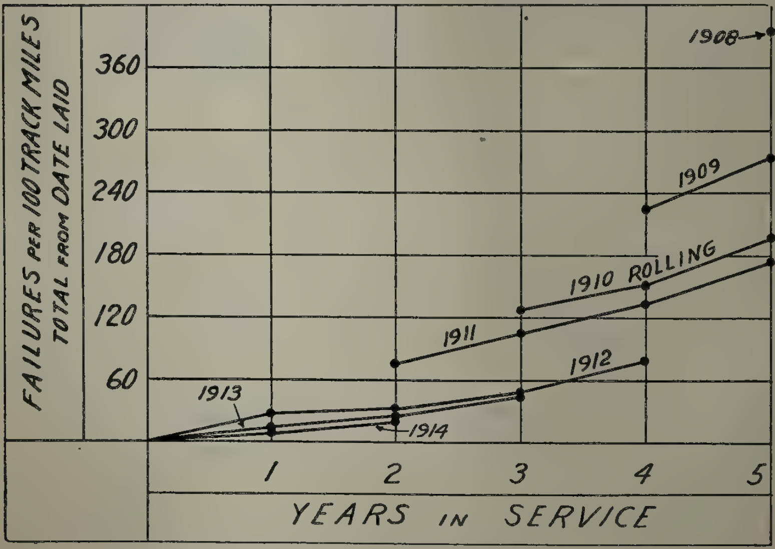

Fig. 3.—The Failures of Rails Rolled in Different Years as Related to Age of Rails.

Table 1

SUMMARY SHOWING TRACK MILES OF RAIL, TOTAL FAILURES AND FAILURES PER 100 TRACK MILES.

GROUPED BY MILLS AND YEARS.

Mill	1911			1912			1913			1914			1915			1916		
	Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures		Trk Mls of Rail Laid	Failures	
		Total	Per 100 Trk Mls		Total	Per/00 Trk Ml		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls		Total	Per 100 Trk Mls
BESSEMER RAIL																		
Algoma				8.76	1	11.4	7.96	15	188.0	81.98	57	69.5						
Bethlehem				36.39	81	222.6				15.77	18	114.1						
Cambria	114.26	403	352.7	89.43	197	220.3	77.64	122	157.1	11.56	3	26.0	12.68	2	15.8			
Carnegie	439.37	879	200.3	70.06	75	107.1	228.57	121	52.9	77.64	14	18.0						
Illinois	733.87	1506	205.2	571.68	520	90.9	227.48	100	43.9	102.02	24	23.5	29.81	3	10.0	135.36	3	2.2
Lackawanna	489.54	1643	335.6	154.12	182	118.1	114.61	17	14.8	72.43	3	4.1	19.65	0	0.0	19.65	0	0.0
Maryland	421.83	278	65.9	517.78	504	97.3	313.71	208	66.3	91.09	27	29.6	28.15	5	17.8	104.66	0	0.0
Totals	2198.87	4709	214.1	1448.22	1560	107.7	969.97	583	60.1	452.49	146	32.3	90.29	10	11.1	259.67	3	1.2
OPEN HEARTH RAIL																		
Algoma										115.78	50	43.2	255.04	18	7.1	138.37	6	4.3
Bethlehem	694.08	2289	329.8	812.72	676	83.2	969.51	510	52.6	563.87	39	6.9	518.94	92	17.7	353.84	16	4.5
Cambria	265.87	684	257.2	552.01	601	108.9	639.68	501	78.3	363.13	136	37.7	334.04	21	6.3	92.85	5	5.4
Carnegie	300.07	497	165.6	620.80	487	78.4	739.89	250	33.8	437.72	52	11.9	709.44	13	1.8	449.59	2	0.4
Colorado	801.58	676	84.3	1527.05	1395	91.3	1056.18	274	26.0	792.88	60	7.6	1246.57	57	4.6	768.13	8	1.0
Dominion	217.52	884	406.4	183.72	162	88.2												
Illinois	1359.59	2428	178.6	2140.74	1382	64.6	2854.12	1256	44.0	1549.74	465	30.0	2037.27	219	10.7	1834.11	15	0.8
Lackawanna	407.33	662	162.5	1101.75	739	67.1	1305.78	678	51.9	766.90	77	10.0	734.09	77	10.5	458.77	11	2.4
Maryland	363.26	245	67.4	34.81	3	8.6	430.95	381	88.4	423.70	107	25.2	330.50	81	24.5	62.79	1	1.6
Pennsylvania	166.01	241	145.2	513.20	240	46.8	610.98	212	34.7	279.86	59	21.1	126.41	8	6.3	47.75	0	0.0
Tennessee	1195.23	737	61.7	1325.91	855	64.5	1758.35	431	24.5	1759.17	292	16.6	998.70	60	6.0	886.84	20	2.3
Totals	5770.54	9343	161.9	8812.71	6540	74.2	10365.44	4493	43.3	7052.75	1337	18.9	7291.00	646	8.8	5093.04	84	1.7
SUMMARY																		
Total, Bess	2198.87	4709	214.1	1448.22	1560	107.7	969.97	583	60.1	452.49	146	32.3	90.29	10	11.1	259.67	3	1.2
Total, O.H.	5770.54	9343	161.9	8812.71	6540	74.2	10365.44	4493	43.3	7052.75	1337	18.9	7291.00	646	8.8	5093.04	84	1.7
Grand Total	7969.41	14052	176.3	10260.93	8100	78.9	11335.41	5076	44.8	7505.24	1483	19.8	7381.29	656	8.9	5352.71	87	1.6

Table 2.

SUMMARY FROM FOUR YEARS REPORTS SHOWING TRACK MILES, TOTAL FAILURES AND FAILURES PER 100 TRACK MILES.

SHOWING BESSEMER, OPEN HEARTH AND TOTAL.

Service	Five Years			Four Years			Three Years			Two Years			One Year			Several Months		
	Trk Miles of Rail Laid	Failures		Trk Miles of Rail Laid	Failures		Trk Miles of Rail Laid	Failures		Trk Miles of Rail Laid	Failures		Trk Miles of Rail Laid	Failures		Trk Miles of Rail Laid	Failures	
		Total	Per100 TrkMls		Total	Per100 TrkMls		Total	Per100 TrkMls		Total	Per100 TrkMls		Total	Per100 TrkMls		Total	Per100 TrkMls
FROM 1913 REPORT																		
Year Rolled	1908			1909			1910			1911			1912			1913		
Total Bess.	2068.16	8548	413.3	3065.49	9179	299.4	3991.21	7640	186.9	1973.70	2610	132.2	559.63	325	58.1	430.35	21	4.9
Total O. H.	1133.19	4198	370.5	3275.05	5029	153.6	5868.97	4767	81.3	4562.35	2420	53.0	6546.11	1725	26.3	5418.29	97	1.8
Grand Total	3201.35	12746	398.1	6340.54	14208	224.1	9860.18	12227	124.0	6536.05	5030	77.0	7105.74	2050	28.9	5848.64	118	2.0
FROM 1914 REPORT																		
Year Rolled	1909			1910			1911			1912			1913			1914		
Total Bess.	3026.03	11316	373.9	4010.42	8874	221.3	1658.23	2646	159.6	671.91	425	63.3	481.95	140	29.1	141.54	3	2.1
Total O. H.	3761.36	7289	198.5	6014.43	6435	107.1	4438.25	3708	83.5	6938.69	2006	28.9	8293.49	955	11.5	4626.80	53	1.1
Grand Total	6697.39	18605	277.8	10024.85	15309	152.7	6096.58	6354	104.4	7610.60	2431	32.1	8775.44	1095	12.5	4768.34	56	1.2
FROM 1915 REPORT																		
Year Rolled	1910			1911			1912			1913			1914			1915		
Total Bess.	4678.46	12344	236.9	2411.10	4441	184.2	1657.33	1108	66.9	998.05	352	35.2	380.02	53	15.1	99.12	0	0.0
Total O H.	6908.97	10637	154.0	5569.65	6194	111.2	8716.85	4011	46.0	9670.54	2404	24.8	6681.22	531	7.9	4187.14	31	0.8
Grand Total	11587.43	22981	198.5	7980.75	10635	133.3	10374.18	5119	49.3	10668.59	2756	25.8	7061.24	584	8.2	4286.26	31	0.7
FROM 1916 REPORT																		
Year Rolled	1911			1912			1913			1914			1915			1916		
Total Bess.	2198.87	4709	214.1	1448.22	1560	107.7	969.97	583	60.1	452.49	146	32.3	90.29	10	11.1	259.67	3	1.2
Total O. H.	5770.54	9343	161.9	8812.71	6540	74.2	10365.44	4493	44.3	7052.75	1337	18.9	7291.00	646	8.8	5093.04	84	1.7
Grand Total	7969.41	14052	176.3	10260.93	6100	78.9	11335.41	5076	44.8	7505.24	1483	19.8	7381.29	656	8.9	5352.71	87	1.6

Table 3

Comparison of Failures for the Different Mills, using 100 as the Average of Failures of all Mills for Each Years Rollings

	1911		1912		1913		1914	
Mill	Relative Failures	Rank	Relative Failures	Rank	Relative Failures	Rank	Relative Failures	Rank
BESSEMER								
Illinois	95.8	3	84.4	1	73.0	2	117.5	3
Lackawanna	156.7	4	109.7	4	24.6	1	20.5	1
Carnegie	93.6	2	99.4	3	88.0	3	90.0	2
Maryland	30.8	1	90.3	2	110.3	4	148.0	5
Cambria	164.7	5	204.5	5	261.4	5	130.0	4
OPEN HEARTH								
Tennessee	38.1	1	86.9	3	56.6	1	87.8	5
Colorado	52.1	3	123.1	8	60.0	2	40.2	2
Pennsylvania	89.7	4	63.1	2	80.1	4	111.6	6
Carnegie	102.3	6	105.7	6	78.1	3	63.0	4
Lackawanna	100.4	5	90.4	5	119.9	6	52.9	3
Maryland	41.6	2	11.6	1	204.1	9	133.6	7
Illinois	110.4	7	87.1	4	101.6	5	158.7	8
Bethlehem	203.7	9	112.1	7	121.5	7	36.8	1
Cambria	158.8	8	146.7	9	180.8	8	199.4	9

Table 4

FAILURES FOR VARIOUS AGES OF RAIL PER 100 TRACK MILES.

BESSEMER

Year Rolled		Years Service					Years Service					
	0	1	2	3	4	5	0	1	2	3	4	5
			Algoma						Cambria			
1908						684.4						134.0
1909					312.3						323.1	325.9
1910				397.7		140.7				207.3	295.4	405.6
1911			342.3						58.1	157.6	254.6	352.7
1912		155.6			11.4			24.7	118.0	126.3	220.3	
1913				188.0			0.0	4.0	20.1	157.1		
1914		21.7	69.5				0.0	8.6	26.0			
1915							0.0	15.8				
1916												
			Carnegie						Illinois			
1908						416.4						491.2
1909					1050.2	1249.0					146.4	168.8
1910				277.1	361.0	482.1				187.9	196.4	205.9
1911			83.1	125.0	163.1	200.3			110.2	191.3	183.1	205.2
1912		19.2	72.9	141.9	107.1			44.1	13.1	54.8	90.9	
1913	8.7	15.8	29.8	52.9			0.0	3.1	28.3	43.9		
1914	0.0	0.0	18.0				0.0	20.7	23.5			
1915							0.0	10.0				
1916							2.2					
			Lackawanna						Maryland			
1908						466.7						222.9
1909					53.6	104.3					285.9	272.8
1910				122.4	174.4	219.4				107.7	141.5	183.2
1911			212.7	263.2	285.5	335.6			31.4	46.6	66.1	65.9
1912		9.1	112.1	101.5	118.1			54.2	54.8	64.9	97.3	
1913	0.0	0.0	26.2	14.8			0.9	59.4	58.2	66.3		
1914	0.0	0.0	4.1				3.3	15.2	29.6			
1915	0.0	0.0					0.0	17.8				
1916	0.0						0.0					
			All Mills									
1908						413.4						
1909					299.4	373.9						
1910				186.9	221.3	236.9						
1911			132.2	159.6	184.2	214.1						
1912		58.8	63.3	66.9	107.7							
1913	4.9	29.1	35.2	60.1								
1914	2.1	15.1	32.3									
1915	0.0	11.1										
1916	1.2											

Table 5

FAILURES FOR VARIOUS AGES OF RAIL PER 100 TRACK MILES

OPEN HEARTH

Year Rolled	Years Service						Years Service					
	0	1	2	3	4	5	0	1	2	3	4	5
	Algoma						Bethlehem					
1908						482.9						503.7
1909					203.7						466.1	530.9
1910				431.0		13.8				174.0	245.0	330.9
1911			219.7						113.3	195.3	251.7	329.8
1912		124.0						11.9	32.0	52.1	83.2	
1913							1.6	13.4	26.9	52.6		
1914		19.0	43.2				0.0	3.8	6.9			
1915	1.4	7.1					0.0	17.7				
1916	4.3						4.5					
	Cambria						Carnegie					
1908												
1909					244.8	326.6					104.1	137.1
1910				98.5	136.4	201.0				98.9	112.9	101.1
1911			73.7	126.1	227.7	257.2			71.5	108.9	123.1	165.6
1912		17.1	41.8	74.2	108.9			12.3	30.9	55.3	78.4	
1913	7.1	26.7	49.5	78.3			2.5	8.9	19.4	33.8		
1914	1.7	15.8	37.7				0.8	5.5	11.9			
1915	1.0	6.3					0.3	1.8				
1916	5.4						0.4					
	Colorado						Dominion					
1908						45.5						1396.9
1909					22.4	34.2					272.6	
1910				19.6	23.4	60.9				830.5		159.9
1911			15.8	31.0	52.6	84.3			246.9		162.3	406.4
1912		18.3	40.9	55.6	91.3			426.0		33.7	88.2	
1913	1.2	3.9	11.0	26.0								
1914	1.0	3.7	7.6									
1915	0.2	4.6										
1916	1.0											
	Illinois						Lackawanna					
1908												143.5
1909					151.9	219.7					100.1	117.8
1910				88.4	136.8	206.2				42.7	90.3	148.9
1911			67.5	94.0	107.7	178.6			29.5	57.1	108.6	162.5
1912		7.4	23.2	39.2	64.6			4.8	20.1	39.6	67.1	
1913	1.1	10.0	21.9	44.0			2.3	17.2	31.4	51.9		
1914	1.0	11.6	30.0				0.3	1.8	10.0			
1915	0.1	10.7					0.2	10.5				
1916	0.8						2.4					
	Maryland						Pennsylvania					
1908												72.8
1909											86.3	101.4
1910				69.6	104.8	163.7				81.4	110.9	123.8
1911			32.9	49.5	58.5	67.4			34.6	79.6	119.0	145.2
1912		11.3	5.8	18.1	8.6			5.3	15.6	27.5	46.8	
1913	0.9	28.6	74.1	88.4			1.1	9.6	21.0	34.7		
1914	1.1	13.3	25.2				2.5	8.2	21.1			
1915	8.3	24.5					0.0	6.3				
1916	1.6						0.0					
	Tennessee						All Mills					
1908						86.5						370.5
1909					11.1	83.7					163.6	198.5
1910				32.4	47.8	55.2				81.3	107.1	154.0
1911			14.9	25.1	40.8	61.7			53.0	83.5	111.2	161.9
1912		7.3	32.9	43.9	64.5			26.3	28.9	46.0	74.2	
1913	1.5	5.7	16.5	24.5			1.8	11.5	24.8	43.3		
1914	1.7	7.5	16.6				1.1	7.9	18.9			
1915	1.3	6.0					0.8	8.8				
1916	2.3						1.6					

Table 6

AVERAGE WEIGHTS OF RAILS

Compiled from Tonnages Used in This Report

Mill	1911	1912	1913	1914	1915	1916
Bessemer.						
Algoma	- -	80.0	80.0	94.9	- -	- -
Bethlehem	- -	88.2	- -	90.0	- -	- -
Cambria	86.8	86.2	85.5	85.0	85.0	- -
Carnegie	92.0	90.6	96.1	90.4	- -	- -
Illinois	86.8	85.8	85.2	83.2	85.0	80.3
Lackawanna	90.2	90.8	83.2	85.9	85.0	85.0
Maryland	86.6	93.9	90.2	94.2	88.4	85.0
Average	88.6	89.5	89.1	89.5	86.7	82.5
Open Hearth						
Algoma	- -	- -	- -	95.6	91.5	91.3
Bethlehem	90.4	92.2	95.3	97.5	99.3	97.9
Cambria	92.5	96.4	93.2	101.4	100.5	103.7
Carnegie	95.3	96.5	96.6	98.9	98.6	103.7
Colorado	87.8	87.1	88.2	86.5	87.6	88.9
Dominion	97.4	90.8	- -	- -	- -	- -
Illinois	89.2	91.4	92.3	92.8	94.0	94.1
Lackawanna	90.7	91.9	95.3	93.6	96.9	94.4
Maryland	90.7	85.0	92.3	92.2	101.7	99.1
Pennsylvania	96.9	93.3	97.0	97.3	99.9	101.9
Tennessee	83.7	85.1	87.2	88.1	88.2	88.3
Average	89.4	90.6	92.3	92.7	94.3	93.7

Table 7. Sheet 1

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Bessemer - Algoma Steel Corporation													
1912	80	ASCE	.50	.60	1100	8.76	-	-	1	-	1	11.4	Tem.& NO
1913	80	ASCE	.50	.60	1000	7.96	-	-	-	15	15	188.0	Tem.& NO
1914	80	ASCE	.50	.60	1000	7.96	-	1	-	3	4	50.2	Tem.& NO
	90	ARA-A	.45	.55	3768	26.64	12	-	-	11	23	86.3	GT
	100	ARA-A	.45	.55	1909	12.15	6	1	-	1	8	65.9	GT
	100	ASCE	.45	.55	4010	25.52	7	4	-	4	15	58.7	GT
	100	ASCE	.60	.70	1527	9.71	-	-	-	7	7	72.0	MC
		Totals			12214	81.98	25	6	-	26	57	69.5	
Bessemer - Bethlehem Steel Company													
1912	85	ASCE	.59	.72	1623	12.15	2	-	-	-	2	16.5	Southern
	90	B&O	.45	.55	3418	24.24	41	1	-	37	79	325.9	B&O
		Totals			5041	36.39	43	1	-	37	81	222.6	
1914	90	B&O	.45	.55	2232	15.77	11	-	-	7	18	114.1	B&O
Bessemer - Cambria Steel Company													
1911	85	ASCE	.43	.53	2989	22.38	33	4	7	7	51	228.0	Southern
	85	ASCE	.43	.53	6813	51.01	40	14	10	21	85	166.6	CNO&TP
	90	ASCE	.43	.53	5780	40.87	258	6	2	1	267	653.2	K&M
		Totals			15582	114.26	331	24	19	29	403	352.7	
1912	85	PS	.45	.55	1162	8.69	11	1	1	4	17	195.6	PRR
	85	PS	.45	.55	1909	14.23	5	2		4	11	77.3	GR&I
	85	PS	.45	.55	1002	7.50	3	-	4	1	8	106.7	GR&I
	85	ASCE			5179	38.77	28	8	2	7	45	116.1	CNO&TP
	90	ASCE	.43	.53	2863	20.24	116	-	-	-	116	573.1	K&M
		Totals			12115	89.43	163	11	7	16	197	220.3	
1913	85	ASCE	.43	.53	7046	52.75	71	12	3	26	112	212.1	CNO&TP
	85	ASCE	.43	.53	2298	17.20	3	1	2	3	9	52.3	Southern
	90	ASCE	.43	.53	1087	7.69	1	-	-	-	1	13.0	K&M
		Totals			10431	77.64	75	13	5	29	122	157.1	
1914	85	ASCE	.43	.53	1544	11.56	3	-	-	-	3	26.0	Southern
1915	85	ASCE	.43	.53	1694	12.68	1	-	1	-	2	15.8	Southern
Bessemer - Carnegie Steel Company													
1911	80	ASCE	.43	.53	3174	25.25	5	5	6	10	26	103.0	T&OC
	85	PS	.45	.55	3349	25.07	17	7	5	43	72	287.1	PL-NW
	85	PS	.45	.55	6652	49.80	37	2	-	20	59	118.5	PL-SW
	90	ARA-A	.45	.55	3037	21.47	48	13	3	12	76	353.9	B&O
	90	ARA-B	.45	.55	5707	40.35	34	11	-	92	137	339.5	B&O
	90	ARA-B	.45	.55	2700	19.09	28	3	5	8	44	230.5	NP
	90	ASCE	.45	.55	15342	108.47	137	16	8	111	272	250.7	Erie
	100	ARA-B	.48	.58	2389	15.20	8	4	-	22	34	223.7	P&LE
	100	ARA-B	.50	.60	3250	20.68	9	1	-	7	17	82.2	B&LE
	100	ARA-B	.48	.58	2477	15.76	-	7	-	3	10	63.0	P&LE
	100	PS	.45	.55	10955	69.71	10	7	5	27	49	70.3	PL-NW
	100	PS	.45	.55	4482	28.52	21	5	1	56	83	291.0	PL-SW
		Totals			63514	439.37	354	81	33	411	879	200.3	
1912	85	ASCE	.43	.53	5874	43.98	-	2	-	1	3	6.8	Mon.
	100	ARA-B	.50	.60	4098	26.08	14	-	-	58	72	276.1	B&LE
		Totals			9972	70.06	14	2	-	59	75	107.1	
1913	85	PS	.45	.55	5162	38.57	11	2	-	11	24	62.2	PL-NW
	85	PS	.45	.55	2111	15.80	11	1	-	10	22	139.2	PL-SW
	90	ASCE	.45	.55	1000	7.07	-	1	-	1	2	28.3	Montour
	100	PS	.45	.55	10127	64.44	4	2	-	8	14	21.7	PL-NW
	100	PS	.45	.55	9272	59.00	7	2	-	3	12	20.3	PL-SW
	100	ARA-B	.50	.60	6865	43.69	14	1	-	32	47	107.6	B&LE
		Totals			34537	228.57	47	9	-	65	121	52.9	
1914	85	ASCE	.43	.53	4300	32.19	3	1	1	1	6	18.6	CNO&TP
	90	ASCE	.45	.55	4260	30.12	4	-	-	3	7	23.2	Montour
	100	PS	.45	.55	2425	15.33	1	-	-	-	1	6.5	PL-SW
		Totals			10985	77.64	8	1	1	4	14	18.0	

Table 7, Sheet 2

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon Min.	Specified Carbon Max.	Total Tons Laid	Equiv. Track Miles	Failures to Date Head	Failures to Date Web	Failures to Date Base	Failures to Date Brkn	Failures to Date Total	Per 100 Trk Mls	R. R.
Bessemer - Illinois Steel Company													
1911	75	MP			6936	58.84	-	-	-	1	1	2.0	MP
	80	ASCE	.40	.50	3570	28.40	-	-	-	3	3	10.6	CinN
	80	ASCE	.43	.53	12277	94.76	39	8	67	108	222	234.3	NYO&W
	80	ASCE	.45	.55	2064	16.42	16	7	3	27	53	322.8	B&OCT
	85	ASCE	.43	.53	1867	13.98	4	-	18	2	24	171.7	Southern
	85	KCS			6014	45.03	-	-	-	-	-	0.0	KCS
	85	MP			1133	8.48	-	-	-	-	-	0.0	KCS
	85	PS	.45	.55	9946	74.46	27	9	26	134	196	263.2	PL-SW
	85	PS	.45	.55	1055	7.89	4	-	9	18	31	392.9	PL-NW
	85	PS	.45	.55	3800	28.45	11	2	8	20	41	144.1	Vandalia
	90	ARA-A	.43	.53	25904	183.16	56	9	37	153	255	139.3	CM&StP
	90	ARA-A	.55	.65	7568	53.55	16	-	1	20	37	69.1	BP
	90	ARA-B	.43	.53	4210	29.77	6	-	12	33	51	171.4	CI&L
	90	ASCE	.45	.55	4791	33.87	46	19	83	322	470	1387.6	Erie
	100	ARA-A	.45	.55	7019	44.61	22	2	15	29	68	152.4	CM&StP
	100	PS	.45	.55	1917	12.20	25	3	1	25	54	442.6	PL-SW
		Totals			100071	733.87	282	59	280	895	1506	205.2	
1912	75	ASCE	.40	.50	7244	61.46	14	3	71	67	155	252.2	CM&STP
	75	MP			5674	48.14	20	1	-	2	23	47.8	MP
	80	ARA-A	.40	.50	7940	63.16	3	-	3	6	12	19.0	GT
	85	ASCE	.43	.53	2685	20.10	6	1	8	-	15	74.6	Southern
	85	ASCE	.43	.53	4200	31.44	8	2	6	69	85	270.3	NYC&StL
	85	KCS			2137	16.00	-	-	-	-	-	0.0	KCS
	x90	ARA-A	.59	.72	1000	7.07	1	-	-	-	1	14.1	CB&Q
	+90	ARA-A	.43	.53	37622	266.01	35	1	15	119	170	64.0	CM&StP
	z90	ARA-A	.43	.53	4980	35.21	5	1	3	25	34	96.5	CM&StP
	+100	ARA-A	.45	.55	3629	23.09	3	1	5	16	25	108.4	CM&StP
		Totals			77111	571.68	85	10	111	304	520	90.9	
1913	75	ASCE	.40	.50	6145	52.14	4	-	41	18	63	121.2	CM&StP
	85	ARA-A			5250	39.30	3	6	1	3	13	33.1	NYC&StL
	85	KCS			2726	20.41	-	-	-	-	-	0.0	KCS
	+90	ARA-A	.43	.53	5318	37.60	3	-	2	5	10	26.6	CM&StP
	z90	ARA-A	.43	.53	6269	58.47	8	3	-	3	14	24.0	CM&StP
	+90	ARA-B	.45	.55	2766	19.56	-	-	-	-	-	0.0	NP
		Totals			30474	227.48	18	9	44	29	100	43.9	
1914	75	ASCF	.40	.50	2103	17.84	5	1	4	10	20	112.0	CM&StP
	85	ARA-A	.43	.53	5250	39.30	1	1	-	2	4	10.1	NYC&StL
	85	ASCE	.43	.53	2489	18.63	-	-	-	-	-	0.0	Southern
	85	KCS			3507	26.25	-	-	-	-	-	0.0	KCS
		Totals			13349	102.02	6	2	4	12	24	23.5	
1915	85	ARA-A	.45	.55	2625	19.65	-	1	-	2	3	15.2	NYC&StL
	85	MP			1357	10.16	-	-	-	-	-	0.0	KCS
		Totals			3982	29.81	-	1	-	2	3	10.0	
1916	75	ASCE	.40	.50	6605	56.04	-	-	-	-	-	0.0	CM&StP
	75	MP			1818	15.43	1	-	-	-	1	6.5	MP
	85	ARA-A			2625	19.65	-	-	-	-	-	0.0	NYC&StL
	85	ASCE	.41	.51	4433	33.21	-	-	-	-	-	0.0	Southern
	85	ASCE	.41	.51	1573	11.03	-	-	2	-	2	18.1	CNO&TP
		Totals			17054	135.36	1	-	2	-	3	2.2	

+ Ferro Titanium Alloy Added x Electric z Copper

Table 7, Sheet 3

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rolled	Lbs Per Yd.	Sec	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
		Bessemer - Lackawanna Steel Company											
1911	80	ASCE	.43	.53	1794	14.27	1	-	-	1	2	14.0	NYSW
	80	ASCE	.40	.50	5053	40.20	31	1	4	24	60	149.0	GT
	+80	Dudley	.52	.65	2750	21.87	2	3	421	79	505	2309.1	Rutland
	+80	Dudley	.55	.65	9043	71.94	13	1	52	106	172	239.1	NYC-E
	85	ASCE	.43	.53	2625	19.65	7	3	15	20	45	229.0	NYC&StL
	85	PS	.45	.55	3043	22.78	8	4	-	3	15	65.8	PRR
	+90	ARA-A	.43	.53	3000	21.21	50	22	134	167	373	1758.6	CB&Q
	90	ARA-B	.45	.55	5658	40.01	-	-	-	1	1	2.5	NP
	90	ASCF	.45	.55	4317	30.52	5	2	-	9	16	52.4	Erie
	90	ASCE	.45	.55	3150	22.27	12	2	2	18	34	152.6	P&R
	+90	ASCE	.45	.55	1072	7.58	-	-	-	5	5	65.9	Erie
	+100	ARA-A	.45	.55	7000	44.52	48	20	1	6	75	168.4	CB&Q
	+100	ASCE	.60	.70	2630	16.73	3	1	7	4	15	89.5	MC
	100	ASCE	.45	.55	2301	14.64	16	4	1	8	29	198.2	Erie
	+100	Dudley	.60	.70	6404	40.75	29	1	86	91	207	507.8	NYC-E
	+100	Dudley	.60	.70	5540	35.26	9	1	13	25	48	136.1	B&A
	100	PS	.45	.55	3982	25.34	25	7	1	8	41	161.8	PRR
		Totals			69362	489.54	259	72	737	575	1643	335.6	
1912	80	ASCE	.40	.50	3030	24.55	-	-	6	11	17	69.2	GT
	85	ASCE	.43	.53	4200	31.44	1	5	-	5	11	35.0	NYC&StL
	+90	ARA-A	.43	.53	1000	7.07	-	-	-	4	4	56.6	CM&StP
	+90	ARA-B	.45	.55	3046	21.54	1	-	-	3	4	18.6	NP
	+90	ASCE	.43	.53	1980	14.00	-	1	2	3	6	42.8	StL-SF
	+100	ARA-A	.45	.55	2050	13.04	7	3	-	5	15	115.0	C&EI
	e100	PS (1)	.45	.55	1000	6.36	24	2	1	1	28	440.2	PRR
	e100	PS (2)	.45	.55	1000	6.36	15	3	-	-	18	285.3	PRR
	e100	PS (3)	.45	.55	1002	6.38	4	4	-	-	8	125.4	PRR
	e100	PS (4)	.45	.55	1001	6.37	10	3	-	-	13	204.1	PRR
	e100	PS (5)	.45	.55	1026	6.53	22	1	-	1	24	367.5	PRR
	100	PS	.45	.55	1647	10.48	23	3	2	6	34	324.4	PRR
		Totals			21982	154.12	107	25	11	39	182	118.1	
1913	70	ASCE	.45	.55	1400	12.73	-	-	-	-	-	0.0	W&LE
	+80	ASCE	.48	.58	1009	8.02	-	-	-	-	-	0.0	MM&SF
	80	ASCE	.40	.50	3162	25.15	9	-	-	-	9	35.7	GT
	85	ARA-A	.43	.53	5250	39.30	3	3	-	1	7	17.8	NYC&StL
	+90	ARA-B	.45	.55	4160	29.41	1	-	-	-	1	3.4	NP
		Totals			14981	114.61	13	3	-	1	17	14.8	
1914	80	ASCE	.48	.58	1215	9.66	-	-	-	-	-	0.0	MM&SF
	85	ARA-A	.43	.53	5250	39.30	1	-	-	2	3	7.6	NYC&StL
	+90	ARA-B	.45	.55	3320	23.47	-	-	-	-	-	0.0	NP
		Totals			9785	72.43	1	-	-	2	3	4.1	
1915	85	ARA-A	.45	.55	2625	19.65	-	-	-	-	-	0.0	NYC&StL
1916	85	ARA-A	.45	.55	2625	19.65	-	-	-	-	-	0.0	NYC&StL
		Bessemer - Maryland Steel Company											
1911	70	ASCE	.35	.45	11299	102.72	5	2	2	10	19	18.5	FEC
	80	ASCE	.70	.85	3364	26.76	1	-	1	-	2	7.5	CNE
	85	ASCE	.48	.58	1501	11.24	5	1	1	9	16	142.3	Virginian
	85	ASCE	.43	.53	3373	25.25	5	2	1	1	9	35.7	Southern
	85	KCS			1879	14.07	-	-	-	-	-	0.0	KCS
	85	PS	.45	.55	6643	49.74	20	8	3	15	46	92.5	PRR
	90	ARA-B	.43	.53	4000	28.28	3	-	-	3	6	21.2	C&O
	+90	ARA-B	.45	.55	2543	17.98	11	1	-	14	26	144.6	B&O
	90	ASCE	.42	.52	1400	9.76	1	1	-	3	5	57.2	P&R
	100	ARA-A	.50	.60	2561	16.29	10	-	5	1	16	98.0	CRRNJ
	+100	ARA-B	.46	.56	1732	11.02	19	2	1	12	34	308.5	B&O
	100	ARA-B	.62	.75	1967	12.52	2	1	-	-	3	23.9	N&W
	100	ASCE			1000	6.36	-	-	-	-	-	0.0	RF&P
	100	NYNH&H	.44		1003	6.38	-	-	-	2	2	31.3	B&M
	m100	NYNH&H	.45	.55	1022	6.50	1	1	-	-	2	30.8	NYNH&H
	100	PS	.45	.55	11094	70.60	22	19	3	33	77	109.1	PRR
	100	P&R	.55	.65	1000	6.36	9	2	-	2	13	204.4	P&R
		Totals			57381	421.83	115	40	18	105	278	65.9	

+ Ferro Titanium Alloy Added. e Ferro Titanium Experiment. m Mayari Bessemer

Table 7, Sheet 4

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rolled	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Bessemer - Maryland Steel Company - Continued													
1912	m80	ASCE	.45	.55	1704	13.55	-	-	-	1	1	7.4	NYNH&H
	m80	Dudley	.40	.50	4876	38.79	3	11	13	12	39	100.5	NYC-E
	85	ASCE	.48	.58	3314	24.81	6	-	1	5	12	48.4	Virginian
	m85	ASCE	.40	.50	3370	25.23	-	1	-	4	5	19.8	Southern
	90	ARA-A	.55	.65	4167	29.40	6	-	-	-	6	20.4	SP
	m90	ARA-A	.43	.53	2000	14.14	1	1	-	3	5	35.4	CM&StP
	m90	ARA-B	.52		7000	49.49	-	-	-	1	1	2.0	C&O
	m90	ARA-B	.45	.55	1715	12.13	23	-	2	2	27	222.6	NP
	m90	GN	.43	.53	4660	32.95	7	-	35	63	105	318.6	GN
	+100	ARA-B	.46	.56	9833	62.57	35	5	-	32	72	114.9	B&O
	100	ASCE			1000	6.36	-	-	-	-	-	0.0	RF&P
	m100	Dudley	.40	.50	2002	12.74	-	-	-	1	1	7.9	NYC-E
	100	NYNH&H	.53		1670	10.63	1	37	20	2	60	564.6	B&M
	m100	NYNH&H	.45	.55	5205	33.12	2	1	9	6	18	54.3	NYNH&H
	m100	PS	.45	.55	3984	25.35	11	2	3	-	16	63.1	PL-NW
	100	PS	.45	.55	19881	126.52	50	58	5	23	136	107.5	PRR
		Totals			76381	517.78	145	116	88	155	504	97.3	
1913	75	ASCE	.38	.48	9800	83.15	-	-	-	-	-	0.0	AT&SF
	m85	ASCE	.40	.50	6289	47.08	3	1	1	-	5	10.6	Southern
	90	ARA-A			1101	7.78	3	-	-	-	3	38.6	C&A
	m90	ARA-B	.52		2000	14.14	2	-	1		3	21.2	C&O
	m90	ARA-B	.45	.55	1196	8.46	-	-	-	-	-	0.0	NP
	m100	PS	.45	.55	2627	16.71	6	-	1	1	8	47.8	PL-NW
	100	PS	.45	.55	18245	116.10	46	15	3	9	73	62.9	PRR
	m100	PS	.45	.55	1030	6.55	7	-	-	27	34	519.1	PL-SW
	100	PRR			1158	7.37	12	-	-	-	12	163.0	CV
	k100	P&R	.42	.52	1001	6.37	70	-	-	-	70	1098.9	P&R
		Totals			44447	313.71	149	16	5	38	208	66.3	
1914	65	ASCE	.43	.53	3403	25.48	3	-	-	1	4	15.7	Southern
	m90	ARA-B	.43	.53	2000	14.14	-	-	-	-	-	0.0	C&O
	100	ARA-B	.45	.55	5342	34.00	2	4	-	13	19	55.8	B&O
	m100	PS.	.45	.55	1245	7.92	3	-	-	1	4	50.5	PL-SW
	100	PRR	.45	.55	1500	9.55	-	-	-	-	-	0.0	CV
		Totals			13490	91.09	8	4	-	15	27	29.6	
1915	85	ASCE	.41	.51	2911	21.79	2	-	-	3	5	23.0	Southern
	100	ASCE			1000	6.36	-	-	-	-	-	0.0	RF&P
		Totals			3911	28.15	2	-	-	3	5	17.8	
1916	85	ASCE	.41	.51	13979	104.66	-	-	-	-	-	0.0	Southern

+ Ferro Titanium Alloy Added

k Entire tonnage removed from track worn out in 18 months - 2 years

m Mayari Bessemer

Table 7, Sheet 5

Total Rail Failures From Date Rolled to October 31st, 1916

Year Rolled	Lbs Per Yd.	Sec.	Specified Carbon Min.	Specified Carbon Max.	Total Tons Laid	Equiv. Track Miles	Failures to Date Head	Web	Base	Brkn	Total	Per 100 Trk Mls	R. R.
						Open Hearth - Algoma Steel Corporation							
1914	90	ARA-A	.63	.76	4190	29.63	9	-	1	4	14	47.2	GT
	90	ASCE	.60	.73	1854	13.10	3	-	-	-	3	22.9	CCC&StL
	100	ARA-A	.63	.76	7095	45.15	8	-	-	2	10	22.1	GT
	100	ASCE	.62	.75	1088	6.92	-	-	-	3	3	43.3	MC
	100	ASCE	.63	.76	3165	20.98	16	-	-	4	20	95.3	GT
		Totals			17392	115.78	36	-	1	13	50	43.2	
1915	80	ASCE	.60	.70	1000	7.96	-	-	-	-	-	0.0	Tem.&NO
	80	ASCE	.55	.68	1621	12.89	1	-	-	-	1	7.8	T&OC
	85	CPR	.58	.72	2404	18.00	-	-	-	-	-	0.0	GT
	90	ARA-A	.63	.76	18926	133.82	5	4	1	-	10	7.5	IC
	90	ARA-B	.63	.76	2500	17.68	3	-	-	2	5	28.2	HV
	100	ARA-A	.62	.75	2992	19.04	-	-	-	2	2	10.5	CRI&P
	100	ARA-B	.63	.76	1463	9.31	-	-	-	-	-	0.0	HV
	100	ASCE	.62	.75	5710	36.34	-	-	-	-	-	0.0	MC
		Totals			36664	255.04	9	4	1	4	18	7.1	
1916	85	MP			1436	10.75	-	-	-	-	-	0.0	KCS
	90	ARA-A	.63	.76	11593	81.97	-	2	-	-	2	2.4	IC
	90	ARA-B	.63	.76	1989	14.06	1	-	-	-	1	7.1	HV
	90	ASCE	.60	.73	1149	8.12	-	-	-	-	-	0.0	T&OC
	100	ARA-B	.63	.76	1516	9.65	-	-	-	2	2	20.7	HV
	100	ASCE	.62	.75	2174	13.82	1	-	-	-	1	7.0	MC
		Totals			19857	138.37	2	2	-	2	6	4.3	
						Open Hearth - Bethlehem Steel Company							
1911	75	Dudley			4235	35.93	-	1	-	-	1	2.8	SAL
	80	ASCE	.62	.75	3299	26.24	1	5	4	7	17	64.8	NYNH&H
	85	ASCE	.62	.75	2963	22.18	3	2	-	48	53	238.9	N&W
	85	ASCE	.67	.80	7080	53.00	15	2	29	190	236	445.3	MeC
	85	ASCE	.67	.80	17200	128.77	12	3	17	70	102	79.5	B&M
	85	ASCE	.62	.75	4917	36.80	1	3	6	13	23	62.5	NYO&W
	90	ASCE	.70	.85	4950	35.00	57	2	2	247	308	880.0	P&R
	90	ASCE	.65	.75	2102	14.86	6	-	-	3	9	60.5	Erie
	90	ASCE	.52	.65	8166	57.74	75	1	-	32	108	187.1	D&H
	91	DL&W	.67	.80	1962	13.72	19	1	2	53	75	546.6	DL&W
	100	ARA-A	.72	.85	11606	73.86	255	37	18	643	953	1291.3	CRRNJ
	100	ASCE	.62	.75	3927	24.99	23	2	4	3	32	128.1	NYC-W
	100	ASCE	.70	.83	4057	25.82	-	-	-	2	2	7.4	LI
	100	Dudley	.62	.75	2299	14.63	3	3	1	2	9	61.5	NYC-E
	100	NYNH&H	.70	.83	4384	27.90	5	6	2	13	26	93.2	NYNH&H
	100	NYNH&H	.70	.83	1000	6.36	-	-	2	3	5	79.3	B&M
	100	PS	.62	.75	3077	19.58	3	2	-	73	78	398.4	PRR
	101	DL&W	.70	.83	7613	47.97	38	5	11	81	135	281.4	DL&W
	110	LV	.63	.76	4967	28.73	90	7	2	18	117	407.2	LV
		Totals			99804	694.08	606	82	100	1501	2289	329.8	
1912	80	ASCE	.62	.75	3116	24.79	-	-	-	3	3	12.1	NYNH&H
	80	ASCE	.59	.72	6800	54.09	1	-	2	4	7	12.9	L&NE
	80	ASCE	.62	.75	1981	15.76	-	3	-	11	14	88.8	CNE
	85	ASCE	.62	.75	2936	21.91	1	1	-	1	3	13.7	NYO&W
	85	ASCE	.67	.80	8000	59.89	5	-	8	55	68	113.5	MeC
	85	ASCE	.67	.80	1571	11.76	4	6	13	60	83	705.5	B&M
	85	Dudley	.62	.75	5556	41.59	2	3	1	3	9	21.6	SAL
	90	ARA-A	.59	.72	2000	14.14	3	-	1	-	4	28.3	CM&StP
	90	ARA-B	.59	.72	2428	17.17	15	-	2	1	18	104.8	NP
	90	ASCE	.62	.75	14259	100.82	13	1	-	10	24	23.8	D&H
	90	ASCE	.67	.80	5045	35.67	-	2	-	3	5	14.0	P&R
	90	GN	.59	.72	9982	70.58	3	-	1	-	4	5.6	GN
	91	DL&W	.64	.77	3587	25.03	9	1	1	9	20	79.9	DL&W
	100	ARA-A	.67	.80	2735	17.40	2	-	-	-	2	11.5	CRRNJ
	100	ARA-A	.63	.76	15150	96.41	185	3	2	25	215	223.0	LV
	100	ARA-B	.70	.80	4233	26.93	36	2	1	40	79	293.3	B&O
	100	ARA-B	.62	.75	3350	21.32	1	-	-	-	1	4.7	Erie
	100	ARA-B	.62	.75	3800	24.18	4	-	-	-	4	14.2	N&W
	100	Dudley	.62	.75	7386	47.00	2	1	-	-	3	6.4	NYC-E
	100	NYNH&H	.70	.83	3438	21.88	10	7	-	3	20	91.4	NYNH&H
	100	PS	.62	.75	4317	27.47	1	3	1	5	10	36.4	PRR
	101	DL&W	.70	.83	3897	24.55	7	-	1	32	40	162.9	DL&W
	110	LV	.63	.76	2140	12.38	28	10	1	1	40	323.1	LV
		Totals			117707	812.72	352	43	35	266	676	82.7	

Table 7, Sheet 6

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Bethlehem Steel Company - Continued													
1913	72	NP	.52	.65	3984	35.21	-	-	-	-	-	0.0	NP
	80	ASCE	.62	.75	1085	8.63	-	2	-	1	3	34.8	NYNH&H
	80	ASCE	.70	.83	1233	9.80	-	1	-	-	1	10.2	LI
	85	ASCE	.67	.80	10000	74.86	2	-	3	38	43	57.4	MeC
	85	ASCE	.67	.80	4600	34.48	-	2	3	2	7	20.3	B&M
	90	ARA-A	.59	.72	2105	14.88	-	-	-	1	1	6.7	CM&StP
	90	ARA-B	.62	.75	4534	32.05	1	-	-	1	2	6.2	NYO&W
	90	ARA-B	.63	.76	2624	18.55	14	-	-	3	17	91.6	B&O
	90	ARA-B	.59	.72	1444	10.21	2	-	-	-	2	19.6	NP
	90	ASCE	.62	.75	7376	52.15	2	-	-	1	3	5.8	D&H
	90	ASCE	.67	.80	3005	21.25	-	-	-	2	2	9.0	CRRNJ
	90	ASCE	.67	.80	5310	37.54	2	-	1	4	7	18.6	P&R
	90	GN	.59	.72	10060	71.13	13	1	24	24	62	87.2	GN
	91	DL&W	.64	.77	1902	13.30	1	-	-	5	6	45.0	DL&W
	100	ARA-A	.63	.76	18374	116.93	93	7	1	8	109	93.2	LV
	100	ARA-A	.63	.76	1523	9.69	2	-	-	-	2	20.6	CRI&P
	100	ARA-A	.67	.80	4325	27.52	4	1	-	1	6	21.8	CRRNJ
	100	ARA-A	.70	.85	2123	13.51	11	2	-	7	20	148.0	L&HR
	100	ARA-A	.63	.76	4000	25.45	3	1	4	-	8	31.4	Erie
	100	ARA-B	.63	.76	1072	6.82	10	2	1	19	32	469.2	Virginian
	100	ARA-B	.63	.76	1624	10.34	1	-	-	5	6	58.0	B&O
	100	ARA-B	.62	.75	5300	33.72	9	1	-	7	17	50.4	N&W
	100	ASCE	.70	.83	2837	18.05	-	-	-	-	-	0.0	LI
	100	NYNH&H	.70	.83	10607	67.50	2	1	1	-	4	5.9	NYNH&H
	100	NYNH&H	.70	.83	3500	22.27	2	1	1	2	6	26.9	B&M
	100	P&R	.67	.80	2720	17.31	-	2	-	4	6	34.7	P&R
	100	PS	.62	.75	3261	20.75	1	-	-	-	1	4.8	PRR
	105	Dudley	.62	.75	9530	57.76	-	-	-	-	-	0.0	NYC-E
	+105	Dudley	.62	.75	1033	6.26	2	-	-	2	4	63.9	NYC-E
	110	LV	.63	.76	12903	74.64	100	11	3	2	116	155.4	LV
	+110	LV	.63	.76	1201	6.95	9	1	1	6	17	244.6	LV
		Totals			145195	969.51	286	36	43	145	510	52.6	
1914	80	ASCE	.53	.66	1296	10.31	-	-	-	-	-	0.0	CNE
	85	ASCE	.63	.76	1630	12.20	-	-	-	-	-	0.0	B&M
	90	ARA-A	.59	.72	1931	13.65	-	-	1	-	1	7.3	CM&StP
	90	ARA-B	.62	.75	3172	22.40	-	-	-	-	-	0.0	NYO&W
	90	ASCE	.67	.80	5042	35.65	1	-	-	3	4	11.2	P&R
	90	ASCE	.62	.75	12000	84.85	-	-	-	-	-	0.0	D&H
	91	DL&W	.64	.77	2350	16.43	-	-	-	1	1	6.0	DL&W
	100	ARA-A	.62	.75	5000	31.82	1	-	-	-	1	3.1	Erie
	100	ARA-A	.63	.76	26237	166.97	18	-	1	1	20	12.0	LV
	100	ARA-A	.67	.80	3866	24.60	-	-	-	-	-	0.0	CRRNJ
	100	ARA-B	.62	.75	3000	19.10	1	-	-	1	2	10.4	C&O
	100	ARA-B	.63	.76	1056	6.72	-	-	-	-	-	0.0	Virginian
	100	ARA-B	.62	.75	4100	26.09	2	-	-	-	2	7.6	N&W
	100	NYNH&H	.63	.76	1798	11.44	-	-	-	-	-	0.0	B&M
	100	NYNH&H	.63	.76	1066	6.78	-	1	-	-	1	14.7	NYNH&H
	100	PS	.62	.75	4422	28.14	-	1	-	2	3	10.7	PRR
	105	Dudley	.62	.75	2030	12.30	-	-	-	-	-	0.0	NYC-E
	110	LV	.63	.76	5950	34.42	4	-	-	-	4	11.6	LV
		Totals			85946	563.87	27	2	2	8	39	6.9	

+ Ferro Titanium Alloy Added.

Table 7, Sheet 7

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mle	
Open Hearth - Bethlehem Steel Company - Continued													
1915	80	ASCE	.53	.66	1711	13.61	-	-	-	-	-	0.0	NYNH&H
	90	ARA-A	.62	.75	1000	7.07	-	-	-	-	-	0.0	CB&Q
	90	ARA-B	.59	.72	1500	10.61	27	2	1	9	39	367.5	C&O
	90	ARA-B	.62	.75	2133	15.08	-	-	-	-	-	0.0	NYO&W
	90	ASCE	.62	.75	2063	14.58	-	-	-	-	-	0.0	D&H
	90	GN	.59	.72	14800	104.64	12	-	1	3	16	15.3	GN
	100	ARA-A	.67	.80	1178	7.58	2	-	-	1	3	40.0	CRRNJ
	100	ARA-A	.70	.85	1038	6.61	-	-	-	-	-	0.0	L&HR
	100	ARA-A	.62	.75	4992	31.77	3	-	-	3	6	18.9	Erie
	100	ARA-A	.63	.76	4738	30.15	-	-	-	-	-	0.0	LV
	100	ARA-B	.62	.75	4866	30.96	1	-	-	-	1	3.2	N&W
	100	ARA-B	.59	.74	4500	28.63	4	-	-	-	4	13.9	C&O
	100	P&R	.63	.76	3100	19.72	-	-	-	-	-	0.0	P&R
	100	PS	.60	.75	1440	9.23	1	2	1	10	14	151.7	PRR
	100	PS	.62	.75	1440	9.23	-	-	-	-	-	0.0	PRR
	101	DL&W	.64	.77	4216	26.56	-	-	-	-	-	0.0	DL&W
	105	DL&W	.64	.77	5222	31.64	2	3	-	2	7	22.1	DL&W
	105	Dudley	.62	.75	3092	18.74	-	-	-	-	-	0.0	B&A
	105	Dudley	.62	.75	1240	7.52	-	-	-	-	-	0.0	NYC-E
	107	NYNH&H	.62	.75	12228	72.72	-	-	-	1	1	1.4	NYNH&H
	125	PS	.68	.82	2808	14.29	-	-	-	-	-	0.0	PRR
	135	CRRNJ	.82	.95	1694	8.00	-	-	-	1	1	12.5	CRRNJ
		Totals			80999	518.94	52	7	3	30	92	17.7	
1916	80	ASCE	.70	.83	1418	11.29	-	-	-	-	-	0.0	LI
	85	ASCE	.62	.75	4550	34.06	-	-	-	-	-	0.0	McC
	90	ARA-A	.59	.72	1999	14.13	-	-	-	-	-	0.0	CM&StP
	90	ARA-B	.62	.75	2423	17.13	-	-	-	1	1	5.8	NYO&W
	90	ARA-B	.59	.72	2452	17.34	-	1	-	-	1	5.8	NP
	90	ARA-B	.62	.70	1000	7.07	-	-	-	-	-	0.0	C&O
	90	ASCE	.62	.75	3807	26.93	-	-	-	-	-	0.0	D&H
	90	ASCE	.62	.75	1204	8.51	-	-	-	-	-	0.0	CRRNJ
	100	ARA-A	.70	.85	2634	16.76	-	-	-	-	-	0.0	L&HR
	100	ARA-A	.67	.80	2862	18.21	-	-	-	-	-	0.0	CRRNJ
	100	ARA-A	.63	.76	5392	34.31	-	-	-	-	-	0.0	LV
	100	ARA-B	.62	.74	6000	38.20	-	-	-	-	-	0.0	C&O
	100	ARA-B	.62	.75	3438	21.88	-	-	-	-	-	0.0	N&W
	100	P&R	.67	.80	2960	18.83	-	-	-	-	-	0.0	P&R
	100	PS	.60	.75	4290	27.30	1	-	-	-	1	3.7	PRR
	101	DL&W	.64	.77	1022	6.44	-	-	-	-	-	0.0	DL&W
	105	DL&W	.64	.77	1326	8.04	-	-	-	-	-	0.0	DL&W
	125	PS	.68	.82	1852	9.43	-	-	-	7	7	74.2	PRR
	135	CRRNJ	.82	.95	1290	6.10	-	-	-	6	6	98.2	CRRNJ
	136	LV	.76	.89	2538	11.88	-	-	-	-	-	0.0	LV
		Totals			54457	353.84	1	1	-	14	16	4.5	
Open Hearth - Cambria Steel Company													
1911	85	ASCE	.62	.75	3390	25.38	2	2	1	2	7	27.6	N&W
	85	PS	.62	.75	7488	56.06	27	48	2	20	97	173.0	PRR
	90	ARA-B	.65	.80	4508	31.80	24	10	-	74	108	339.6	B&O
	90	ARA-B	.63	.76	6490	45.89	19	8	1	6	34	74.1	HV
	100	ARA-B	.70	.80	3709	23.60	88	3	1	23	115	487.3	B&O
	100	PS	.62	.75	13065	83.14	75	132	7	109	323	388.5	PRR
		Totals			38650	265.87	235	203	12	234	684	257.2	
1912	72	NP	.52	.65	1172	10.36	1	-	-	1	2	19.3	NP
	85	ASCE	.62	.75	3300	24.70	-	-	-	8	8	32.4	N&W
	90	ARA-A	.63	.76	1566	11.07	6	1	-	-	7	63.1	UP
	90	ARA-A	.59	.72	2000	14.14	2	-	-	-	2	14.1	CM&StP
	90	ARA-B	.63	.76	5108	36.12	2	1	-	1	4	11.1	HV
	90	ARA-B	.63	.76	1000	7.07	-	-	-	1	1	14.1	CI&L
	90	GN	.59	.72	9840	68.58	8	-	-	5	13	18.2	GN
	100	ARA-A	.70	.80	1065	6.78	-	-	-	1	1	14.7	B&O
	100	ARA-A	.63	.76	2360	15.02	9	5	1	1	16	106.5	LV
	100	ARA-B	.70	.80	23957	152.48	100	15	-	119	234	153.4	B&O
	100	ARA-B	.62	.75	1097	6.98	1	-	-	-	1	14.3	N&W
	100	PS	.62	.75	21739	138.34	98	66	3	130	297	214.6	PRR
	100	PS	.62	.75	1429	9.09	1	1	-	-	2	22.0	PL-SW
	100	PS	.62	.75	8064	51.31	9	2	-	2	13	25.1	PL-NW
		Totals			83697	552.01	237	91	4	269	601	108.9	

Table 7, Sheet 8

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
						Open Hearth - Cambria Steel Company - Continued							
1913	72	NP	.52	.65	6965	61.56	-	-	-	2	2	3.2	NP
	85	ASCE	.62	.75	2559	19.16	-	-	-	2	2	10.4	N&W
	85	PS	.62	.75	1916	14.34	-	59	1	-	60	418.4	PRR
	85	PS	.62	.75	2589	19.39	-	13	-	-	13	67.0	GR&I
	90	ARA-A	.59	.72	4809	34.00	2	-	-	-	2	5.9	CM&StP
	90	ARA-A	.63	.76	8562	60.53	-	7	-	-	7	11.5	B&O
	90	ARA-B	.63	.76	3793	26.82	1	4	-	19	24	89.5	HV
	90	ARA-B	.63	.76	1000	7.07	-	-	-	-	-	0.0	CI&L
	90	ASCE	.59	.75	1717	12.14	-	-	-	-	-	0.0	CRRNJ
	90	ASCE	.59	.72	1566	11.07	1	-	-	-	1	9.0	K&M
	90	GN	.59	.72	4860	34.36	5	4	1	4	14	40.8	GN
	100	ARA-A	.63	.76	2208	14.05	-	-	-	-	-	0.0	B&O
	100	ARA-B	.63	.76	23008	146.42	68	2	1	96	167	114.1	B&O
	100	ARA-B	.62	.75	2683	17.07	1	-	-	3	4	23.4	N&W
	100	PS	.62	.75	25410	161.70	57	73	1	74	205	126.8	PRR
		Totals			93645	639.68	135	162	4	200	501	78.3	
1914	90	ARA-A	.63	.76	1050	7.43	-	1	-	1	2	26.9	B&O
	90	ARA-A	.59	.72	4952	35.01	-	-	-	-	-	0.0	CM&StP
	90	ARA-B	.62	.75	3099	21.91	1	-	-	1	2	9.1	NP
	90	ARA-B	.63	.76	1070	7.57	1	1	-	-	2	26.4	HV
	100	ARA-B	.63	.76	11003	70.02	16	-	1	44	61	87.1	B&O
	100	ARA-B	.63	.76	1535	9.77	-	-	-	1	1	10.2	HV
	100	ARA-B	.62	.75	2304	14.66	1	-	-	1	2	13.6	N&W
	100	PS	.60	.75	9777	62.22	7	7	1	5	20	32.1	PRR
	100	PS	.62	.75	13363	85.04	4	6	-	9	19	22.3	PRR
	125	PS	.78	.92	9723	49.50	16	4	-	7	27	54.5	PRR
		Totals			57876	363.13	46	19	2	69	136	37.7	
1915	85	ASCE	.62	.75	1462	10.94	-	-	-	-	-	0.0	N&W
	90	ARA-A	.62	.75	1000	7.07	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.62	.75	6350	44.91	-	-	-	-	-	0.0	B&O
	100	ARA-B	.62	.75	13171	83.82	1	-	-	2	3	3.6	B&O
	100	ARA-B	.62	.75	2045	13.01	-	-	-	-	-	0.0	N&W
	100	PS	.60	.75	18117	115.30	2	1	1	7	11	9.5	PRR
	125	PS	.68	.82	10587	58.99	6	-	-	1	7	11.9	PRR
		Totals			52732	334.04	9	1	1	10	21	6.3	
1916	90	ARA-A	.59	.72	3009	21.27	-	-	-	-	-	0.0	CM&STP
	90	ARA-B	.62	.75	1371	9.69	-	-	-	-	-	0.0	NP
	90	GN	.59	.72	1464	10.35	-	-	-	-	-	0.0	GN
	100	ARA-B	.62	.75	3508	22.32	2	-	-	-	2	8.9	N&W
	125	PS	.68	.82	3734	19.01	1	1	-	-	2	10.5	PRR
	+125	PS	.68	.82	2006	10.21	-	-	1	-	1	9.8	PRR
		Totals			15092	92.85	3	1	1	-	5	5.4	

+ Ferro Titanium Alloy Added

Table 7, Sheet 9

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Carnegie Steel Company													
1911	85	PS	.62	.75	2005	15.01	7	9	-	1	17	113.2	PRR
	90	ARA-A	.65	.80	5190	36.69	14	8	-	32	54	147.2	B&O
	90	ARA-B	.65	.85	6661	47.09	40	12	2	83	137	290.9	B&O
	90	ASCE	.70	.85	5040	35.63	-	2	-	11	13	36.4	P&R
	100	ARA-A	.63	.76	1024	6.52	-	16	1	7	24	368.1	LV
	100	ARA-B	.62	.75	4284	27.26	11	6	-	6	23	84.4	P&LE
	100	ARA-B	.62	.75	2976	18.94	5	13	-	-	18	95.4	P&LE
	100	PS	.62	.75	11514	73.27	23	79	-	36	138	188.3	PRR
	100	PS	.62	.75	6233	39.66	17	14	2	40	73	184.0	PL-NW
		Totals			44927	300.07	117	159	5	216	497	165.6	
1912	80	ARA-B	.52	.65	2170	17.26	31	-	-	2	33	191.2	NYS&W
	85	PS	.62	.75	3986	29.84	-	-	-	-	-	0.0	PL-NW
	90	ARA-A	.70	.80	2569	10.16	2	2	-	4	8	44.1	CH&D
	90	ARA-A	.65	.80	8287	58.59	32	-	1	16	49	83.6	B&O
	90	ARA-B	.59	.72	16640	117.65	22	5	-	16	43	36.5	Erie
	90	ARA-B	.65	.85	2187	15.46	91	7	-	20	118	763.2	B&O
	90	ASCE	.60	.73	1455	10.28	10	8	-	7	25	243.1	W&LE
	100	ARA-A	.70	.80	1218	7.75	9	9	-	7	25	322.5	B&O
	100	ARA-B	.62	.75	1585	10.09	-	3	-	3	6	59.4	P&LE
	100	ARA-B	.62	.75	15500	98.63	11	6	2	16	35	35.4	N&W
	100	ARA-B	.62	.75	4704	29.94	3	1	-	7	11	36.3	P&LE
	100	ARA-B	.70	.80	7723	49.15	4	3	1	18	26	52.9	B&O
	100	PS	.62	.75	16628	105.81	14	30	-	19	63	59.5	PL-NW
	100	PS	.62	.75	9459	60.19	16	9	2	18	45	74.8	PL-SW
		Totals			94111	620.80	245	83	6	153	487	78.4	
1913	80	ARA-A	.53	.66	2370	18.84	7	2	-	2	11	58.4	Erie
	85	ASCE	.62	.75	4275	32.00	2	-	-	3	5	15.6	N&W
	85	WP			1113	8.34	-	-	-	1	1	12.0	WP
	90	ARA-A	.63	.76	7824	55.32	2	-	-	3	5	9.1	B&O
	90	ARA-A	.63	.76	4155	29.38	1	-	-	-	1	3.4	CH&D
	90	ASCE	.60	.73	4627	32.71	6	1	-	4	11	33.6	W&LE
	90	ASCE	.70	.85	4994	35.31	1	-	1	3	5	14.1	P&R
	100	ARA-A	.63	.76	8781	55.88	3	1	3	9	16	28.6	B&O
	100	ARA-A	.63	.76	13135	83.59	13	4	1	10	28	33.5	Erie
	100	ARA-A	.63	.76	7327	46.63	21	3	-	1	25	53.6	LV
	100	ARA-A	.63	.76	3650	23.23	3	-	-	1	4	17.2	Erie
	100	ARA-B	.63	.76	8168	51.98	10	1	-	31	42	80.8	B&O
	100	ARA-B	.62	.75	13252	84.33	-	1	-	2	3	3.5	N&W
	100	ARA-B	.62	.75	3615	23.00	1	-	-	3	4	17.6	P&LE
	100	ARA-B	.62	.75	2715	17.28	1	-	-	8	9	52.2	P&LE
	100	ARA-B	.65	.75	2391	15.22	-	-	-	1	1	6.6	B&LE
	100	PS	.62	.75	7658	48.73	3	2	-	9	14	28.7	PL-SW
	100	PS	.62	.75	12282	78.12	42	5	2	16	65	83.2	PL-NW
		Totals			112332	739.89	116	20	7	107	250	33.8	
1914	90	ARA-A	.63	.76	1414	10.00	-	-	-	1	1	10.0	CH&D
	90	ASCE	.67	.80	5028	35.55	-	1	-	-	1	2.8	P&R
	100	ARA-A	.63	.76	4194	26.69	1	-	-	-	1	3.7	B&O
	100	ARA-A	.62	.75	1524	9.69	-	1	-	-	1	10.3	LE&E
	100	ARA.A	.62	.75	20528	130.64	4	1	1	2	8	6.1	Erie
	100	ARA-B	.62	.75	8400	53.66	-	-	-	-	-	0.0	N&W
	100	ARA-B	.62	.75	1028	6.54	1	-	-	-	1	15.3	P&LE
	100	ARA-B	.62	.75	1797	11.44	-	2	-	-	2	17.4	P&LE
	100	ARA-B	.63	.76	3159	20.11	-	-	-	13	13	64.7	B&O
	100	ARA-B	.62	.75	2597	16.53	3	-	1	2	6	36.3	B&LE
	100	PS	.62	.75	5289	33.65	1	-	-	-	1	3.0	PL-SW
	100	PS	.62	.75	3140	19.98	-	2	-	10	12	60.1	PRR
	100	PS	.62	.75	9939	63.24	2	-	-	3	5	7.9	PL-NW
		Totals			68037	437.72	12	7	2	31	52	11.9	

Table 7, Sheet 10

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
					Open Hearth - Carnegie Steel Company - Continued								
1915	85	ASCE	.62	.75	1061	7.93	-	-	-	-	-	0.0	N&W
	90	ARA-A	.62	.75	8056	56.95	-	-	-	-	-	0.0	CH&D
	90	ASCE	.63	.76	2306	16.30	-	-	-	-	-	0.0	P&R
	90	ASCE			1528	10.80	-	-	-	-	-	0.0	W&LE
	100	ARA-A	.62	.75	20530	130.65	-	-	-	1	1	0.7	Erie
	100	ARA-A	.62	.75	5334	33.94	1	-	-	1	2	5.9	B&O
	100	ARA-B	.62	.75	5769	36.71	4	-	-	4	8	21.8	B&LE
	100	ARA-B	.62	.75	4755	30.26	-	-	-	-	-	0.0	P&LE
	100	ARA-B	.62	.75	8930	56.82	-	-	-	1	1	1.8	B&O
	100	ARA-B	.62	.75	3746	23.84	-	-	-	-	-	0.0	P&LE
	100	ARA-B	.62	.75	14025	89.25	-	-	-	-	-	0.0	N&W
	100	PS	.60	.75	24380	155.15	1	-	-	-	1	0.6	PL-NW
	100	PS	.60	.75	8433	53.66	-	-	-	-	-	0.0	PL-SW
	100	PS	.60	.75	1129	7.18	-	-	-	-	-	0.0	PRR
			Totals		109982	709.44	6	-	-	7	13	1.8	
1916	90	ASCE	.63	.76	2000	14.14	-	-	-	-	-	0.0	P&R
	100	ARA-B	.63	.76	1006	6.40	-	-	-	-	-	0.0	HV
	100	ARA-B	.62	.75	5819	37.03	1	-	-	-	1	2.7	B&LE
	100	ARA-B	.62	.75	1785	11.36	-	-	-	-	-	0.0	P&LE
	100	ARA-B	.62	.75	12808	81.50	-	-	-	-	-	0.0	N&W
	100	P&R	.67	.80	2061	13.11	-	-	-	-	-	0.0	P&R
	100	PS	.60	.75	25108	159.78	-	-	-	-	-	0.0	PL-NW
	100	PS	.60	.75	10327	65.71	-	-	-	-	-	0.0	PL-SW
	130	PS	.68	.87	12371	60.56	1	-	-	-	1	1.6	PRR
			Totals		73285	449.59	2	-	-	-	2	0.4	
					Open Hearth - Colorado Fuel & Iron Company								
1911	75	CS	.55	.68	8972	76.12	-	-	-	1	1	1.3	OSL
	75	CS	.55	.68	1773	15.04	-	-	-	-	-	0.0	T&NO
	75	CS	.55	.68	2384	20.23	-	-	-	-	-	0.0	H&TC
	85	D&RG	.58	.68	2855	21.37	5	-	-	3	8	37.5	D&RG
	90	ARA-A	.63	.76	9387	66.37	109	18	2	3	132	195.9	OSL
	90	ARA-A			17292	122.26	88	3	-	6	97	79.3	SP
	90	ARA-A	.63	.76	5065	35.81	14	-	-	4	18	50.3	UP
	90	ARA-A	.58	.68	17200	121.60	85	4	3	9	101	83.0	CB&Q
	90	SF	.59	.72	45650	322.78	293	9	-	17	319	98.8	AT&SF
			Totals		110578	801.58	594	34	5	43	676	84.3	
1912	75	CS	.55	.68	5232	44.39	-	-	-	-	-	0.0	UP
	75	CS-R	.63	.76	11557	98.06	-	-	-	2	2	2.0	OSL
	75	"754"	.65	.78	9195	78.02	-	-	-	-	-	0.0	OElec.
	85	ASCE			2042	15.29	-	1	-	-	1	6.5	C&S
	85	ASCE			16986	127.17	12	-	-	4	16	12.6	EP&SW
	85	ASCE			4717	35.32	-	-	-	-	-	0.0	C&S
	85	D&RG	.58	.68	10000	74.87	2	-	-	4	6	8.0	D&RG
	90	ARA-A			5669	40.08	13	1	-	1	15	37.4	SP
	90	ARA-A	.58	.68	35000	247.45	114	5	-	8	127	51.3	CB&Q
	90	ARA-A	.63	.76	4611	32.60	23	2	1	1	27	82.8	OSL
	90	ARA-A	.59	.72	16206	114.59	48	-	-	16	64	55.9	MP-IM
	90	ARA-B	.58	.68	4337	30.67	48	-	1	1	50	163.0	NP
	90	GN	.60	.70	30038	212.40	541	37	31	149	758	356.9	GN
	90	SF	.63	.76	50404	356.39	291	10	3	22	326	91.5	AT&SF
	100	ARA-B	.60	.70	3103	19.75	3	-	-	-	3	15.2	NP
			Totals		209097	1527.05	1095	56	36	208	1395	91.3	
1913	75	CS-R	.63	.76	5769	48.95	-	-	-	-	-	0.0	OSL
	75	CS-R	.55	.68	5346	45.36	2	-	-	-	2	4.4	UP
	85	ASCE			1945	14.56	-	-	-	-	-	0.0	EP&SW
	85	D&RG	.58	.68	10000	74.87	7	1	1	-	9	12.1	D&RG
	90	ARA-A	.58	.68	30000	212.10	28	3	-	1	32	15.1	CB&Q
	90	ARA-A	.63	.76	4900	34.57	-	-	-	34	34	98.6	LA&SL
	90	ARA-A	.62	.75	9968	70.48	7	-	-	-	7	9.9	MP-IM
	90	ARA-A			7065	49.95	6	-	-	1	7	14.0	SP
	90	ARA-B	.58	.68	14655	103.62	70	-	2	5	77	74.3	NP
	90	D&RG	.58	.68	4400	31.11	2	-	-	-	2	6.4	D&RG
	90	SF	.63	.76	52415	370.61	89	-	-	15	104	28.1	AT&SF
			Totals		146463	1056.18	211	4	3	56	274	26.0	

Table 7, Sheet 11

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rolled	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Colorado Fuel & Iron Company - Continued													
1914	75	CS-R	.55	.68	5559	47.17	-	-	-	-	-	0.0	UP
	85	D&RG	.58	.68	2990	22.38	1	-	-	1	2	8.9	U Ry
	90	ARA-A	.63	.76	3500	24.74	-	-	-	-	-	0.0	LA&SL
	90	ARA-A			6723	47.53	5	-	-	-	5	10.5	SP
	90	ARA-A	.62	.75	3536	25.00	-	-	-	1	1	4.0	MP-IM
	90	ARA-A	.62	.75	20000	141.40	17	2	-	-	19	13.4	CB&Q
	90	ARA-B	.58	.68	1010	7.14	9	-	-	-	9	126.1	NP
	90	D&RG	.58	.68	9000	63.64	5	-	-	-	5	7.8	D&RG
	90	SF	.63	.76	58535	413.88	17	1	-	1	19	4.6	AT&SF
	Totals				110853	792.88	54	3	-	3	60	7.6	
1915	85	ASCE			2156	16.14	-	-	-	-	-	0.0	C&S
	90	ARA-A			10826	76.55	-	-	-	-	-	0.0	EP&SW
	90	ARA-A	.63	.76	19795	139.96	17	-	2	-	19	13.6	OSL
	90	ARA-A			3133	22.15	-	-	-	-	-	0.0	EP&SW
	90	ARA-A	.63	.76	14237	100.67	3	1	-	-	4	4.0	UP
	90	ARA-A	.62	.75	15000	106.05	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.63	.76	8460	59.82	4	-	-	-	4	6.7	OSL
	90	ARA-A	.63	.76	12500	88.38	-	-	-	18	18	20.0	LA&SL
	90	ARA-A	.62	.75	8325	58.86	-	-	-	-	-	0.0	MP-IM
	90	ARA-B	.58	.68	3933	27.81	1	-	-	-	1	3.6	NP
	90	D&RG	.62	.75	10000	70.71	1	-	-	-	1	1.4	D&RG
	90	SF	.63	.76	67812	479.47	10	-	-	-	10	2.1	AT&SF
	Totals				176177	1246.57	36	1	2	18	57	4.6	
1916	75	CS-R	.55	.68	4165	35.34	-	-	-	-	-	0.0	StJ&GI
	85	MP	.62	.75	6959	52.10	1	-	-	-	1	1.9	MP-IM
	90	ARA-A	.63	.76	9480	67.03	-	-	-	-	-	0.0	OSL
	90	ARA-A	.63	.76	2200	15.55	-	-	-	-	-	0.0	LA&StL
	90	ARA-A	.62	.75	22970	162.41	6	-	-	-	6	3.7	MP-IM
	90	ARA-A	.63	.76	8041	56.86	-	-	-	-	-	0.0	UP
	90	ARA-A	.62	.75	15000	106.05	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.63	.76	5928	41.92	-	-	-	-	-	0.0	LA&SL
	90	ARA-B	.58	.68	1813	12.82	-	-	-	-	-	0.0	NP
	90	SF	.63	.76	30839	218.05	1	-	-	-	1	0.5	AT&SF
	Totals				107395	768.13	8	-	-	-	8	1.0	
Open Hearth - Dominion Iron and Steel Company													
1911	80	ASCE	.55	.65	3570	28.40	357	9	-	61	427	1503.5	GT
	100	ASCE	.56	.68	29718	189.12	353	42	16	46	457	241.6	GT
	Totals				33288	217.52	710	51	16	107	884	406.4	
1912	80	ASCE	.55	.65	10606	84.37	39	2	4	21	66	78.2	GT
	100	ASCE	.56	.68	15602	99.35	72	4	3	17	96	96.6	GT
	Totals				26208	183.72	111	6	7	38	162	88.2	

Table 7, Sheet 12

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rolled	Lbs Per Yd.	Sec.	Specified Carbon Min.	Specified Carbon Max.	Total Tons Laid	Equiv. Track Miles	Failures to Date Head	Web	Base	Brkn	Total	Per 100 Trk Mls	R. R.
Open Hearth - Illinois Steel Company													
1911	75	CS	.63	.76	12956	109.93	1	-	-	10	11	10.1	OSL
	80	ARA-A	.59	.72	1400	11.14	15	-	2	6	23	206.5	MStP&SsM
	80	ASCE			2701	21.49	3	-	1	30	34	158.2	D&IR
	80	ASCE	.52	.65	3803	30.25	21	-	-	1	22	72.7	IaCent
	85	ASCE	.58	.71	1552	11.62	6	-	-	4	10	86.1	IHB
	85	ASCE			2625	19.65	5	1	22	97	125	636.1	NYC&StL
	85	ASCE	.59	.72	1961	14.68	-	-	1	6	7	47.6	C&EI
	85	ASCE	.58	.71	3368	25.21	-	-	-	11	11	43.6	NYC-W
	85	ASCE	.62	.75	19187	143.65	16	2	38	70	126	92.9	CRI&P
	85	PS	.62	.75	1523	11.40	16	-	4	8	28	245.6	Vandalia
	90	ARA-A	.65	.80	2420	17.11	-	-	-	-	-	0.0	CH&D
	90	ARA-A	.65	.80	3128	22.12	1	-	9	33	43	194.4	B&O
	90	ARA-A	.62	.75	10000	70.70	122	15	45	63	245	346.5	CB&Q
	90	ARA-A	.59	.72	7013	49.59	4	3	4	12	23	46.4	CM&StP
	90	ARA-A	.63	.76	8808	62.28	115	7	22	24	168	269.7	IC
	90	ARA-B	.62	.75	15420	109.03	163	3	52	66	284	260.5	NP
	90	ARA-B	.59	.72	6000	42.42	-	2	-	-	2	4.7	C&O
	90	ASCE	.60	.73	3149	22.27	4	2	3	9	18	80.8	T&OC
	90	ASCE	.60	.73	12000	84.84	25	21	15	74	135	159.1	CCC&StL
	90	GN	.62	.75	25880	183.03	156	9	137	477	779	425.6	GN
	90	SF	.59	.72	9501	67.18	16	7	2	1	26	38.7	AT&SF
	100	ARA-A			3925	24.98	44	10		28	82	328.2	C&A
	100	ARA-A	.62	.75	2991	19.03	-	-	-	1	1	5.3	CM&StP
	100	ARA-B	.62	.75	5000	31.82	12	-	1	24	37	116.2	C&O
	100	ASCE	.62	.75	13159	83.74	16	2	4	37	59	70.4	MC
	100	ASCE	.62	.75	4998	31.80	18	11	13	42	84	264.1	NYC-W
	100	PS	.62	.75	6069	38.63	22	6	1	16	45	116.4	PL-NW
		Totals			190537	1359.59	801	101	376	1150	2428	178.6	
1912	72	NP	.52	.65	3110	27.49	-	-	-	-	-	0.0	NP
	80	ASCE	.52	.65	1501	11.90	1	-	-	-	1	8.4	M&StL
	80	ASCE	.55	.68	3919	31.17	4	-	1	8	13	41.7	T&OC
	80	ASCE	.55	.68	7252	56.88	2	1	9	7	19	33.4	NYC-W
	80	ASCE	.65	.80	1432	11.39	5	-	-	-	5	43.9	B&OCT
	85	ARA-A	.59	.72	19815	148.35	23	1	25	19	68	45.8	MStP&SsM
	85	ASCE	.58	.71	3392	25.39	-	-	-	-	-	0.0	NYC-W
	85	ASCE	.58	.71	1674	12.53	3	-	-	1	4	31.9	I&HB
	85	PS	.59	.72	4141	31.00	6	-	-	-	6	19.4	M&StL
	85	PS	.62	.75	10165	76.10	34	2	1	21	58	76.2	PL-SW
	90	ARA-A	.62	.75	15000	106.05	70	4	8	16	98	92.5	CB&Q
	90	ARA-A	.59	.72	25122	177.63	6	-	-	15	21	11.8	CM&StP
	90	ARA-A		.64	5845	41.33	1	1	-	-	2	4.8	C&EI
	90	ARA-A	.63	.76	10348	73.16	-	-	-	2	2	2.7	CRI&P
	90	ARA-A			3980	28.17	1	-	-	-	1	3.6	SP
	90	ARA-A	.59	.72	8975	63.46	6	1	-	1	8	12.6	MP-IM
	90	ARA-A	.65	.80	2138	15.08	19	3	-	7	29	192.3	B&O
	90	ARA-A	.63	.76	4667	33.00	19	6	6	7	38	115.2	IC
	90	ARA-A			2424	17.13	38	2	-	11	51	297.8	C&A
	90	ARA-A	.63	.76	3796	26.84	8	-	1	9	18	67.1	UP
	90	ARA-A	.65	.80	1080	7.64	-	-	-	-	-	0.0	CH&D
	90	ARA-B	.62	.75	9078	64.19	143	2	33	31	209	325.6	NP
	90	ARA-B		.66	4000	28.28	6	-	-	1	7	24.7	C&O
	90	ARA-B	.63	.76	6000	42.42	37	2	-	5	44	103.7	CI&L
	90	ARA-B	.59	.72	31250	220.96	13	4	1	18	36	16.3	Erie
	90	ARA-B	.45	.49	1032	7.30	-	-	-	4	4	54.8	C&NW
	90	ASCE	.60	.73	4149	29.34	9	-	-	3	12	40.9	T&OC
	90	ASCE			1850	13.08	18	1	-	2	21	160.1	D&IR
	90	ASCE	.60	.73	10500	74.24	24	2	2	7	35	47.1	CCC&StL
	90	ASCE	.43	.53	1129	7.98	2	1	-	7	10	125.3	LE&W
	90	SF	.63	.76	1681	11.89	6	-	-	-	6	50.5	AT&SF
	100	ARA-A	.62	.75	4648	29.58	1	1	1	1	4	13.5	CM&StP
	100	ARA-A	.64	.77	5000	31.80	8	2	1	5	16	50.3	CB&Q
	100	ARA-A	.70	.80	7559	48.10	14	1	4	12	31	64.4	B&O
	100	ARA-A		.68	3012	19.17	3	2	-	4	9	47.0	C&EI
	100	ARA-A	.63	.76	13494	85.87	46	2	-	4	52	60.6	CRI&P
	100	ARA-B	.67		6000	38.18	18	1	-	32	51	133.5	C&O
	100	ASCE	.62	.75	3673	23.37	13	33	2	5	53	226.7	MC
	100	ASCE	.62	.75	10995	69.96	20	13	10	25	68	97.2	NYC-W
	100	C&NW	.62	.75	22895	145.70	72	-	1	31	104	71.0	C&NW
	100	PS	.62	.75	5934	37.88	36	-	2	4	42	110.9	Vandalia
	100	PS	.62	.75	10780	68.60	59	3	2	14	78	113.7	PL-NW
	100	PS	.62	.75	3325	21.16	23	-	1	24	48	226.8	PL-SW
		Totals			307680	2140.74	817	91	111	363	1382	64.6	

Table 7, Sheet 13

Total Rail Failures From Date Rolled to October 31st, 1916

Year Rolled	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Illinois Steel Company - Continued													
1913	75	ASCE	.53	.66	6382	54.15	3	-	-	-	3	5.5	AT&SF
	80	ASCE	.55	.68	2850	22.67	3	-	2	1	6	26.4	NYC-W
	80	ASCE			1657	13.18	-	-	-	-	-	0.0	D&IR
	80	ASCE	.55	.68	2577	20.50	3	3	2	5	13	63.4	T&OC
	80	ASCE	.53	.66	1638	13.03	2	4	-	1	7	53.7	B&OCT
	85	ARA-A	.59	.72	19793	148.18	14	3	8	17	42	28.3	MStP&SsM
	85	ASCE	.43	.53	1741	13.03	1	-	-	-	1	7.7	Southern
	85	ASCE	.58	.71	1350	10.11	4	-	-	4	8	79.1	IHB
	85	ASCE	.58	.71	6141	60.94	1	1	-	7	9	14.8	NYC-W
	85	PS	.59	.72	8425	63.08	-	-	-	-	-	0.0	M&StL
	85	PS	.62	.75	1202	9.00	-	-	-	7	7	77.8	GR&I
	90	ARA-A			37340	264.02	32	5	2	59	98	37.1	SP
	90	ARA-A	.62	.75	25000	176.75	47	4	14	33	98	55.4	CB&Q
	90	ARA-A	.63	.76	11882	84.01	69	4	11	17	101	120.2	IC
	90	ARA-A	.63	.76	8784	62.11	58	1	-	11	70	112.7	UP
	90	ARA-A	.63	.76	13079	92.47	4	-	-	1	5	5.4	CRI&P
	90	ARA-A	.59	.72	13127	92.82	13	-	3	25	41	44.2	CM&StP
	90	ARA-A			11426	80.78	15	6	1	3	25	31.0	C&A
	90	ARA-A	.59	.72	7755	54.83	20	1	1	1	23	41.9	C&EI
	90	ARA-B	.63	.76	4000	28.28	12	-	-	1	13	46.0	CI&L
	90	ARA-B	.66		2000	14.14	-	-	-	-	-	0.0	C&O
	90	ARA-B	.62	.75	23475	165.98	79	2	24	56	161	97.0	NP
	90	ASCE			2446	17.29	11	-	-	3	14	81.0	D&IR
	90	ASCE	.60	.73	5503	38.91	1	1	-	-	2	5.1	T&OC
	90	ASCE	.60	.73	12600	89.09	26	7	4	4	41	46.0	CCC&StL
	90	GN	.59	.72	14590	103.18	11	1	27	13	52	50.4	GN
	90	SF	.63	.76	13480	95.31	21	1	1	3	26	27.3	AT&SF
	100	ARA-A	.62	.75	1939	12.34	4	1	-	1	6	48.6	C&EI
	100	ARA-A	.63	.76	13335	84.86	19	-	1	1	21	24.7	CRI&P
	100	ARA-A	.63	.76	4500	28.64	2	1	1	-	4	13.9	Erie
	100	ARA-A	.64	.77	5000	31.80	1	-	4	-	5	15.7	CB&Q
	100	ARA-A	.62	.75	10072	64.10	-	-	4	4	8	12.4	CM&StP
	+100	ARA-A	.62	.75	1502	9.56	-	-	1	-	1	10.5	CM&StP
	100	ARA-A	.63	.76	9166	58.33	6	-	4	7	17	29.2	B&O
	100	ARA-B		.69	4300	27.36	11	2	-	3	16	58.4	C&O
	100	ASCE	.62	.75	15567	99.06	26	47	3	30	106	107.0	MC
	100	ASCE	.62	.75	15288	97.28	5	1	6	15	27	27.7	NYC-W
	+100	ASCE	.62	.75	2000	12.72	1	-	-	-	1	7.8	NYC-W
	100	C&NW	.62	.75	44124	280.80	28	2	1	21	52	18.5	C&NW
	100	PS	.62	.75	2322	14.78	7	-	1	8	16	108.3	PL-SW
	100	PS	.62	.75	13246	84.28	29	2	-	6	37	42.6	PL-NW
	100	PS	.62	.75	9487	60.37	71	-	-	2	73	120.9	Vandalia
		Totals			414091	2854.12	660	100	126	370	1256	44.0	

+ Ferro Titanium Alloy Used

Table 7, Sheet 14

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Illinois Steel Company - Continued													
1914	75	CS-R	.55	.68	3397	28.82	-	-	-	-	-	0.0	UP
	80	ASCE	.55	.68	2052	16.32	-	-	9	4	13	79.6	NYC-W
	80	ASCE	.55	.68	1578	12.55	1	-	-	4	5	39.8	T&OC
	80	ASCE	.55	.68	1573	12.51	-	-	-	-	-	0.0	MC
	85	ARA-A	.59	.72	12930	96.80	1	-	3	34	38	39.2	MStP&SsM
	85	ASCE	.59	.76	6000	44.92	3	4	10	20	37	82.4	CGW
	85	ASCE	.58	.71	1770	13.25	-	-	-	-	-	0.0	NYC-W
	85	PS	.59	.72	1578	11.80	1	-	1	-	2	17.0	M&StL
	90	ARA-A	.63	.76	28519	201.65	32	-	13	9	54	26.7	IC
	90	ARA-A	.59	.72	9667	68.35	1	-	3	7	11	16.2	CM&StP
	90	ARA-A			6972	49.29	12	-	2	1	15	30.5	C&A
	90	ARA-A	.62	.75	17500	123.73	-	-	-	-	-	0.0	CB&Q
	90	ARA-B	.60	.73	4000	28.28	11	-	-	1	12	42.4	C&O
	90	ARA-B	.62	.75	13906	98.32	30	1	3	27	61	62.0	NP
	90	ARA-B	.45	.49	1004	7.10	1	1	-	22	24	338.0	C&NW
	90	ASCE	.60	.73	7875	55.68	6	-	-	2	8	14.3	CCC&StL
	90	ASCE			1500	10.61	1	-	-	-	1	9.4	D&IR
	90	ASCE	.60	.73	1050	7.42	-	-	-	-	-	0.0	T&OC
	90	GN	.59	.72	9010	63.72	60	2	-	31	93	145.9	GN
	100	ARA-A	.62	.75	3428	21.81	1	-	1	2	4	18.3	CM&StP
	100	ARA-A	.62	.75	5972	38.00	-	-	-	-	-	0.0	Erie
	100	ARA-A	.64	.77	7500	47.70	-	-	-	-	-	0.0	CB&Q
	100	ARA-A	.63	.76	10087	64.19	5	-	1	2	8	12.4	CRI&P
	100	ARA-A	.63	.76	3150	20.04	-	-	-	-	-	0.0	CI&L
	100	ARA-A	.63	.76	4734	30.13	1	-	1	-	2	6.6	B&O
	100	ARA-B	.62	.75	3100	19.73	27	-	-	10	37	187.5	C&O
	100	ASCE	.62	.75	10340	65.80	2	3	2	-	7	10.6	NYC-W
	100	ASCE	.62	.75	3680	23.41	2	-	2	-	4	17.0	MC
	100	C&NW	.62	.75	18416	117.20	5	-	-	-	5	4.2	C&NW
	100	PS	.62	.75	4802	30.12	4	-	-	6	10	33.2	PL-SW
	100	PS	.62	.75	13126	83.53	3	-	-	-	3	3.3	PL-NW
	100	PS	.62	.75	5808	36.96	10	1	-	-	11	29.7	Vandalia
	Totals				226024	1549.74	220	12	51	182	465	30.0	
1915	80	ASCE	.55	.68	1622	12.90	-	-	-	-	-	0.0	LE&W
	80	ASCE	.53	.66	1962	15.60	-	-	-	2	2	12.8	B&OCT
	80	ASCE	.55	.68	2500	19.88	-	-	3	3	6	30.2	NYC-W
	80	ASCE	.55	.68	2943	23.41	-	-	2	3	5	21.3	MC
	80	ASCE	.55	.68	2632	20.91	-	-	-	-	-	0.0	CN
	85	ARA-A	.59	.72	3629	27.17	-	-	-	2	2	7.3	MStP&SsM
	85	ASCE	.58	.71	1299	9.73	-	-	-	1	1	10.3	IHB
	85	ASCE	.59	.76	6000	44.92	2	1	2	7	12	26.7	CGW
	85	ASCE	.58	.71	1500	11.23	-	-	-	-	-	0.0	NYC-W
	85	PS	.59	.72	4346	32.53	-	-	-	-	-	0.0	M&StL
	90	ARA-A	.59	.72	14380	101.68	6	-	7	61	74	73.9	CM&StP
	90	ARA-A	.63	.76	1379	9.75	-	-	-	-	-	0.0	GT
	90	ARA-A	.62	.75	6000	42.42	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.62	.75	2102	14.86	-	-	1	4	5	33.6	B&O
	90	ARA-A	.59	.72	10004	70.73	-	-	-	-	-	0.0	C&EI
	90	ARA-A	.63	.76	8962	63.37	2	-	-	1	3	4.7	UP
	90	ARA-A	.63	.76	7672	54.25	4	1	3	3	11	20.3	IC
	90	ARA-A			11032	78.00	2	-	-	-	2	2.6	C&A
	90	ARA-B	.59	.70	4000	28.28	-	-	-	-	-	0.0	C&O
	90	ARA-B	.45	.49	7200	50.91	-	-	-	5	5	9.8	C&NW
	90	ARA-B	.62	.75	4478	31.66	11	-	-	-	11	34.7	NP
	90	ARA-B	.57	.70	5158	36.47	12	-	-	1	13	35.6	NP
	90	ARA-B	.63	.76	4400	31.11	-	-	-	-	-	0.0	CI&L
	90	ASCE	.60	.73	17000	120.20	3	1	-	-	4	3.3	CCC&StL
	90	GN	.59	.72	3204	22.66	1	-	-	3	4	17.7	GN
	90	SF	.63	.76	12730	90.01	-	-	-	-	-	0.0	AT&SF
	100	ARA-A	.64	.77	9000	57.24	-	-	-	-	-	0.0	CB&Q
	100	ARA-A	.62	.75	5309	33.79	-	-	1	2	3	8.9	B&O
	100	ARA-A	.62	.75	26307	167.41	5	-	1	1	7	4.2	CRI&P
	100	ARA-A	.62	.75	5975	38.02	-	-	1	1	2	5.2	Erie
	100	ARA-A	.63	.76	4608	29.33	-	-	-	-	-	0.0	GT
	100	ARA-B	.59	.75	11500	73.18	15	-	-	2	17	23.2	C&O
	100	ASCE	.62	.75	8613	54.81	-	-	-	-	-	0.0	MC
	100	ASCE	.62	.75	21000	133.64	1	1	-	-	2	1.5	NYC-W
	100	C&NW	.62	.75	20000	127.27	-	1	-	8	9	7.0	C&NW
	100	PS	.60	.75	22800	145.09	1	-	-	2	3	2.1	PL-SW
	100	PS	.52	.75	5197	33.07	1	-	-	-	1	3.0	Vandalia
	100	PS	.60	.75	12539	79.78	15	-	-	-	15	18.8	PL-NW
	Totals				300982	2037.27	81	5	21	112	219	10.7	

Table 7, Sheet 15

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Illinois Steel Company - Continued													
1916	80	ASCE	.53	.66	2061	16.40	-	-	-	-	-	0.0	B&OCT
	80	ASCE	.55	.68	1300	10.34	-	-	-	-	-	0.0	NYC-W
	80	ASCE	.55	.68	2239	17.81	-	-	-	-	-	0.0	LE&W
	85	ARA-A	.59	.72	6227	46.61	-	-	-	-	-	0.0	MStP&SsM
	85	PS	.59	.72	2496	18.70	-	-	-	-	-	0.0	M&StL
	90	ARA-A	.59	.72	8727	61.70	-	-	-	-	-	0.0	CM&StP
	90	ARA-A	.59	.72	1785	12.62	-	-	-	-	-	0.0	M&StL
	90	ARA-A	.63	.76	16057	113.54	-	-	-	-	-	0.0	UP
	90	ARA-A	.63	.76	11068	78.26	6	1	-	1	8	10.2	IC
	90	ARA-A	.62	.75	10000	70.70	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.59	.72	10000	70.70	1	-	-	-	1	1.4	C&EI
	90	ARA-A			12729	90.00	-	-	-	-	-	0.0	C&A
	90	ARA-A	.62	.75	7253	51.28	-	-	-	-	-	0.0	CRI&P
	90	ARA-B	.63	.76	6225	44.01	-	-	-	-	-	0.0	CI&L
	90	ARA-B	.62	.75	7406	52.37	1	-	-	-	1	1.9	NP
	90	ARA-B	.62	.75	3000	21.21	-	-	-	-	-	0.0	C&O
	90	ASCE	.60	.73	20000	141.41	1	-	-	-	1	0.7	CCC&StL
	90	GN	.59	.72	14827	104.13	2	-	-	-	2	1.9	GN
	90	SF	.62	.75	11180	79.04	1	-	-	-	1	1.3	AT&SF
	100	ARA-A	.62	.75	25085	159.63	-	-	-	-	-	0.0	CRI&P
	100	ARA-A	.59	.72	4727	30.08	-	-	-	-	-	0.0	CM&StP
	100	ARA-A	.64	.77	5000	31.80	-	-	-	-	-	0.0	CB&Q
	100	ARA-B	.62	.75	11000	70.00	-	-	-	-	-	0.0	C&O
	100	ASCE	.62	.75	6283	39.98	-	-	-	-	-	0.0	MC
	100	ASCE	.62	.75	1600	10.18	-	-	-	-	-	0.0	NYC-W
	100	PS	.60	.75	8321	52.95	-	-	-	-	-	0.0	PL-NW
	100	PS	.60	.75	23273	148.09	-	-	-	1	1	0.7	PL-SW
	100	PS	.60	.75	5911	37.11	-	-	-	-	-	0.0	Vandalia
	105	Dudley	.62	.75	16407	99.44	-	-	-	-	-	0.0	NYC-W
	105	Dudley	.62	.75	8914	54.02	-	-	-	-	-	0.0	MC
		Totals			271101	1834.11	12	1	-	2	15	0.8	
Open Hearth - Lackawanna Steel Company													
1911	80	Dudley	.55	.68	17834	141.87	8	1	9	60	78	55.0	NYC-E
	85	PS	.62	.75	1600	11.98	2	-	-	1	3	25.0	PRR
	91	DL&W	.67	.80	12485	87.31	48	12	10	152	222	254.3	DL&W
	100	ARA-A	.63	.76	1072	6.82	70	3	3	8	84	1231.7	LV
	100	Dudley	.60	.72	12549	79.86	14	3	5	57	79	98.9	NYC-E
	100	Dudley	.62	.75	7013	44.63	17	3	1	14	35	78.4	B&A
	100	PS	.62	.75	2142	13.63	32	12	-	39	83	609.0	PRR
	101	DL&W	.70	.83	3369	21.23	52	4	1	21	78	367.4	DL&W
		Totals			58064	407.33	243	38	29	352	662	162.5	
1912	72	NP	.52	.65	3404	30.09	-	-	-	-	-	0.0	NP
	80	Dudley	.55	.68	20000	159.10	60	5	4	37	106	66.6	NYC-E
	85	ASCE	.65	.78	4400	32.94	1	1	-	4	6	18.2	B&M
	85	Dudley	.59	.72	6006	44.96	-	-	-	-	-	0.0	SAL
	90	ARA-B	.59	.72	9886	69.90	7	12	2	5	26	37.2	Erie
	90	ASCE	.62	.75	2504	17.64	20	2	-	22	44	249.4	P&R
	90	Dudley	.60	.73	2500	17.68	-	-	-	-	-	0.0	Rutland
	90	CN	.62	.75	38130	269.62	22	-	11	9	42	15.6	GN
	100	ARA-A	.63	.76	5785	36.81	292	9	2	10	313	850.3	LV
	100	Dudley	.60	.72	35545	226.20	6	-	3	15	24	10.6	NYC-E
	100	Dudley	.62	.75	12965	82.51	16	2	1	3	22	26.7	B&A
	100	PS	.62	.75	3872	24.64	28	13	-	66	107	434.3	PRR
	101	DL&W	.70	.83	14230	89.66	25	2	1	21	49	54.7	DL&W
		Totals			159227	1101.75	477	46	24	192	739	67.1	

Table 7. Sheet 16.

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rol-led	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Lackawanna Steel Company - Continued													
1913	80	ARA-A	.53	.66	2150	17.10	-	-	-	-	-	0.0	NYS&W
	80	ASCE	.55	.68	4400	35.00	-	-	5	1	6	17.1	NYC-W
	80	Dudley	.55	.68	22559	179.45	1	2	4	22	29	16.1	NYC-E
	85	ASCE	.65	.78	8602	64.32	3	-	6	7	16	24.8	B&M
	85	Dudley	.62	.75	4201	31.45	2	-	-	-	2	6.3	SAL
	90	ARA-A	.59	.72	4931	34.87	1	1	-	-	2	5.7	CM&StP
	90	ARA-A			1055	7.46	-	-	-	-	-	0.0	C&A
	90	ARA-A	.59	.72	5000	35.35	1	1	4	5	11	31.1	CB&Q
	90	ASCE	.62	.75	2995	21.18	37	3	2	135	177	835.6	P&R
	90	Dudley	.60	.73	2500	17.68	-	-	-	-	-	0.0	Rutland
	90	GN	.62	.75	15180	107.34	30	-	8	16	54	50.3	GN
	91	DL&W	.67	.80	1491	10.43	1	-	-	5	6	57.6	DL&W
	100	ARA-A	.63	.76	8323	52.97	215	4	3	9	231	436.1	LV
	100	ARA-A	.63	.76	8000	50.90	9	-	-	5	14	27.5	Erie
	100	ARA-A	.63	.76	1454	9.25	-	-	-	-	-	0.0	CRI&P
	100	ASCE	.62	.75	5350	34.04	5	-	4	13	22	64.6	MC
	100	PS	.62	.75	14768	93.98	8	6	1	5	20	21.3	PRR
	101	DL&W	.67	.80	11780	74.22	10	1	-	26	37	49.9	DL&W
	105	Dudley	.62	.75	8585	52.03	3	-	1	-	4	7.7	B&A
	105	Dudley	.62	.75	62166	376.76	15	3	17	12	47	12.5	NYC-E
	Totals				195490	1305.78	341	21	55	261	678	51.9	
1914	80	ARA-A	.53	.66	1650	13.12	-	-	-	-	-	0.0	NYS&W
	80	Dudley	.55	.68	22328	177.61	-	-	-	2	2	1.1	NYC-E
	85	ASCE	.59	.76	1000	7.49	1	-	-	-	1	13.4	CGW
	85	ASCE	.63	.76	5000	37.43	-	-	-	-	-	0.0	MC
	85	Dudley	.62	.75	3943	29.51	-	-	-	-	-	0.0	SAL
	90	ARA-A	.59	.72	3000	21.21	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.62	.75	2040	14.42	7	1	-	2	10	69.3	Erie
	90	ARA-A	.59	.72	4965	35.11	-	-	-	-	-	0.0	CM&StP
	90	ARA-B	.62	.75	1278	9.03	-	-	-	1	1	11.1	NYO&W
	90	ASCE	.67	.80	3009	21.27	2	-	-	21	23	108.1	P&R
	91	DL&W	.64	.77	3660	25.59	2	1	-	-	3	11.7	DL&W
	100	ARA-A	.63	.76	4106	26.13	1	1	-	1	3	11.5	LV
	100	ARA-A	.62	.75	2928	18.63	1	-	-	-	1	5.3	Erie
	100	PS	.62	.75	3254	20.71	-	-	-	2	2	9.7	PRR
	+100	PS	.60	.75	2854	18.16	-	-	-	-	-	0.0	PRR
	101	DL&W	.64	.77	4431	28.55	11	-	-	16	27	94.6	DL&W
	105	DL&W	.64	.77	2056	12.46	-	-	-	-	-	0.0	DL&W
	105	Dudley	.62	.75	5070	30.73	-	-	1	-	1	3.3	B&A
	105	Dudley	.62	.75	34980	212.00	2	-	-	1	3	1.4	NYC-E
	+105	Dudley	.62	.75	1277	7.74	-	-	-	-	-	0.0	NYC-E
	Totals				112829	766.90	27	3	1	46	77	10.0	
1915	80	Dudley	.55	.68	6592	52.43	-	-	-	-	-	0.0	NYC-E
	85	ASCE	.62	.75	7723	57.74	-	-	-	-	-	0.0	B&M
	90	ARA-A	.63	.76	1092	7.72	-	-	-	-	-	0.0	GT
	90	ARA-A	.62	.75	3000	21.21	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.63	.76	1015	7.18	-	-	-	-	-	0.0	UP
	90	ARA-B	.62	.75	1516	10.72	-	-	-	-	-	0.0	NYO&W
	90	ARA-B	.59	.72	7624	53.91	2	-	-	1	3	5.6	NP
	90	ASCE	.67	.80	1500	10.60	1	1	-	2	4	37.7	P&R
	90	GN	.59	.72	12477	88.22	2	-	-	2	4	4.5	GN
	100	ARA-A	.62	.75	9524	60.61	-	-	-	-	-	0.0	Erie
	100	ARA-B	.63	.76	1000	6.36	-	-	-	-	-	0.0	Virginian
	100	ARA-B	.62	.75	1011	6.43	4	-	-	-	4	62.2	N&W
	100	ASCE	.62	.75	3500	22.27	1	-	1	-	2	9.0	NYC-W
	100	NYNH&H	.62	.75	3910	24.88	-	-	-	-	-	0.0	B&M
	100	PS	.60	.75	5511	35.08	1	-	-	-	1	2.8	PRR
	105	DL&W	.64	.77	4579	27.75	3	1	1	-	5	18.0	DL&W
	+105	Dudley	.62	.75	2089	12.66	-	-	-	-	-	0.0	NYC-E
	105	Dudley	.62	.75	28072	170.13	-	-	-	-	-	0.0	NYC-E
	105	Dudley	.52	.75	5274	31.96	1	-	-	-	1	3.1	B&A
	107	NYNH&H	.62	.75	2088	12.42	-	-	-	-	-	0.0	NYNH&H
	125	PS	.68	.82	2712	13.81	50	-	1	2	53	383.8	PRR
	Totals				111809.	734.09	65	2	3	7	77	10.5	

+ Ferro Titanium Alloy Used.

Table 7, Sheet 17

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rolled	Lbs Per Yd.	Sec.	Specified Carbon Min.	Specified Carbon Max.	Total Tons Laid	Equiv. Track Miles	Failures to Date Head	Failures to Date Web	Failures to Date Base	Failures to Date Brkn	Failures to Date Total	Failures to Date Per 100 Trk Mle	R. R.
Open Hearth - Lackawanna Steel Company - Continued													
1916	85	ASCE	.62	.75	15620	116.94	-	-	1	-	1	0.9	B&M
	90	ARA-A	.59	.72	6029	42.63	-	-	-	-	-	0.0	CM&StP
	90	ARA-A	.62	.75	5000	35.35	-	-	-	-	-	0.0	CB&Q
	90	ARA-A	.62	.75	2100	14.85	-	-	-	-	-	0.0	NYO&W
	90	ARA-B	.59	.72	5498	38.87	1	-	-	-	1	2.6	NP
	90	Dudley	.60	.73	1414	10.00	-	-	-	-	-	0.0	Rutland
	90	GN	.59	.72	2512	17.76	-	-	-	-	-	0.0	GN
	100	NYNH&H	.62	.75	9785	62.27	-	-	-	-	-	0.0	B&M
	105	DL&W	.64	.77	5130	31.09	-	-	-	-	-	0.0	DL&W
	105	DL&W	.62	.75	8400	50.91	4	-	-	-	4	7.9	B&A
	105	Dudley	.62	.75	4710	28.55	-	-	-	-	-	0.0	NYC-W
	125	PS	.68	.82	1876	9.55	5	-	-	-	5	52.4	PRR
		Totals			68074	458.77	10	-	1	-	11	2.4	
Open Hearth - Maryland Steel Company													
1911	85	ASCE	.55	.68	11000	82.35	8	5	2	1	16	19.4	ACL
	85	ASCE	.59	.72	13300	99.57	1	-	4	19	24	24.2	B&M
	85	Dudley			3927	29.40	4	1	-	2	7	23.8	SAL
	85	PS	.62	.75	1768	13.24	3	8	-	9	20	151.1	PRR
	100	ARA-B	.62	.75	3000	19.10	19	1	-	21	41	214.6	C&O
	100	ARA-B	.62	.75	6216	39.55	28	3	-	6	37	93.5	N&W
	100	ARA-B	.70	.80	1773	11.29	23	2	-	23	48	425.1	B&O
	100	NYNH&H	.62	.75	8500	54.09	11	1	6	17	35	64.7	B&M
	100	PS	.62	.75	2305	14.67	4	3	-	10	17	115.9	PRR
		Totals			51789	363.26	101	24	12	108	245	67.4	
1912	85	ASCE	.55	.68	4650	34.81	-	1	2	-	3	8.6	ACL
1913	80	ASCE	.58	.71	3464	27.55	-	-	-	1	1	3.6	NYNH&H
	80	ASCE	.55	.68	4850	38.58	2	-	-	3	5	12.9	LE&W
	85	ASCE	.62	.75	2011	15.06	2	-	-	2	4	26.5	N&W
	85	ASCE	.55	.68	5950	44.55	3	-	-	-	3	6.7	ACL
	85	Dudley			3255	24.36	2	-	-	1	3	12.3	SAL
	90	ARA-A	.63	.76	7123	50.34	1	1	-	-	2	4.0	SP
	90	ARA-A	.59	.72	1948	13.70	-	-	1	1	2	14.6	CM&StP
	90	ARA-A			1552	10.97	1	2	-	-	3	27.3	SAL
	100	ARA-B	.63	.76	1001	6.37	5	1	1	3	10	157.0	Virginian
	100	ARA-B	.63	.76	17576	111.94	134	7	6	72	219	195.6	B&O
	100	ARA-B	.62	.75	5622	35.77	38	-	-	4	42	117.4	N&W
	100	NYNH&H	.65	.78	1006	6.40	-	-	-	1	1	15.6	NYNH&H
	100	PS	.62	.75	7128	45.36	41	19	3	23	86	189.6	PRR
		Totals			62486	430.95	229	30	11	111	381	88.4	
1914	80	ASCE	.53	.66	2984	23.73	-	-	-	-	-	0.0	NYNH&H
	85	ASCE	.62	.75	2764	20.69	1	-	-	-	1	4.8	N&W
	85	ASCE	.55	.68	17900	134.01	-	-	-	-	-	0.0	ACL
	90	ARA-A	.59	.72	1972	13.94	-	-	-	1	1	7.2	CM&StP
	90	ARA-A	.62	.75	4985	35.24	-	-	-	-	-	0.0	SAL
	100	ARA-B	.62	.75	4050	25.77	-	-	-	1	1	3.9	N&W
	100	ARA-B	.63	.76	1403	8.93	8	5	1	1	15	168.0	Virginian
	100	PS	.60	.75	8064	51.32	6	-	-	-	6	11.7	PRR
	100	PS	.62	.75	17296	110.07	57	19	1	6	83	75.4	PRR
		Totals			61418	423.70	72	24	2	9	107	25.2	
1915	85	ASCE	.62	.75	2702	20.23	-	-	-	-	-	0.0	N&W
	85	ASCE	.62	.75	8500	63.63	-	-	-	-	-	0.0	NC
	90	ARA-B	.59	.72	1000	7.07	10	-	-	1	11	155.5	C&O
	100	ARA-B	.62	.75	3356	21.35	2	1	-	-	3	14.0	N&W
	100	ARA-B	.62	.75	4328	27.57	1	-	1	3	5	18.1	B&O
	100	PS	.60	.75	11188	71.20	23	7	3	5	38	53.4	PRR
	107	NYNH&H	.62	.75	10397	61.80	2	-	-	-	2	3.2	NYNH&H
	125	PS	.68	.82	11324	57.65	22	-	-	-	22	38.2	PRR
		Totals			52795	330.50	60	8	4	9	81	24.5	
1916	90	ARA-A	.59	.72	1999	14.13	-	-	-	-	-	0.0	CM&StP
	100	ARA-B	.62	.75	4001	25.46	-	1	-	-	1	3.9	N&W
	100	P&R			1071	6.82	-	-	-	-	-	0.0	P&R
	107	NYNH&H	.62	.75	2754	16.38	-	-	-	-	-	0.0	NYNH&H
		Totals			9825	62.79	-	1	-	-	1	1.6	

Table 7, Sheet 18

Total Rail Failures From Date Rolled to October 31st, 1916													
Year Rolled	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Pennsylvania Steel Company													
1911	80	ASCE	.70	.85	1626	12.93	-	9	2	-	11	85.1	NYNH&H
	90	ASCE	.70	.85	3500	24.74	17	4	2	76	99	400.1	P&R
	100	ARA-A	.70	.85	1649	10.58	5	4	2	17	28	266.6	CRRNJ
	100	NYNY&H	.70	.85	4916	31.28	-	8	5	19	32	102.3	NYNH&H
	100	"96-A"			1038	6.61	-	-	-	-	-	0.0	CV
	100	P&R	.70	.85	6500	41.36	6	3	-	14	23	55.6	P&R
	100	PS	.62	.75	4040	25.71	12	6	2	23	43	167.3	PRR
	101	DL&W	.70	.83	2032	12.80	-	2	-	3	5	39.1	DL&W
		Totals			25301	166.01	40	36	13	152	241	145.2	
1912	72	NP	.52	.65	1757	15.53	-	-	-	-	-	0.0	NP
	85	ASCE	.62	.75	4485	33.58	1	2	-	10	13	38.7	N&W
	85	ASCE	.55	.68	5990	44.75	-	3	-	-	3	6.6	ACL
	90	ASCE	.67	.80	6504	45.98	4	5	-	15	24	52.2	P&R
	90	GN	.59	.72	24148	170.75	6	3	11	62	82	48.0	GN
	100	"96-A"			2071	13.18	1	-	-	1	2	15.0	CV
	100	ARA-A	.70	.85	6373	40.55	2	-	1	2	5	12.3	CRRNJ
	100	ARA-B	.62	.75	2048	13.03	1	-	13	14	28	214.9	NP
	100	ARA-B	.62	.75	2175	13.20	1	-	-	1	2	15.1	N&W
	100	ARA-B	.62		1000	6.36	-	-	-	1	1	15.7	C&O
	100	PR	.67	.80	9951	63.32	7	1	-	12	20	31.5	P&R
	100	PS	.62	.75	4973	31.65	14	3	-	6	23	72.7	PRR
	101	DL&W	.62	.75	2202	13.87	-	-	-	-	-	0.0	DL&W
	135	CRRNJ	.90	1.00	1581	7.45	32	-	1	4	37	496.6	CRRNJ
		Totals			75258	513.20	69	17	26	128	240	46.8	
1913	72	NP	.52	.65	2984	26.37	-	-	-	1	1	3.8	NP
	50	ASCE	.58	.71	1265	10.06	-	-	-	-	-	0.0	NYNH&H
	80	ASCE	.65	.78	1005	8.00	-	-	2	1	3	37.5	CNE
	85	ASCE	.53	.68	1010	7.57	-	-	-	-	-	0.0	ACL
	90	ARA-B	.62	.75	1045	7.39	-	-	3	4	7	94.7	NP
	90	ARA-B	.59	.72	10442	73.82	11	-	6	6	23	31.2	NP
	90	GN	.59	.72	4882	34.52	7	5	7	9	28	81.1	GN
	100	ARA-A	.63	.76	10306	65.68	41	-	3	2	46	70.1	LV
	100	ARA-A	.70	.85	3882	24.70	5	5	2	14	26	105.2	CRRNJ
	100	ARA-B	.62	.75	1904	12.12	-	-	-	6	6	49.5	NP
	100	NYNH&H	.65	.78	11736	74.68	5	4	3	5	17	22.8	NYNH&H
	100	NYNH&H	.63	.76	3550	22.51	-	1	3	1	5	22.2	B&M
	100	P&R	.67	.80	18988	120.83	5	1	-	5	11	9.1	P&R
	100	PS	.62	.75	7723	49.15	6	4	-	3	13	26.4	PRR
	100	"96-A"			1536	9.80	1	-	-	-	1	10.0	CV
	101	DL&W	++	++	7980	50.28	4	6	-	1	11	21.9	DL&W
	135	CRRNJ	.90	1.05	2887	13.60	12	1	-	1	14	103.0	CRRNJ
		Totals			93125	610.98	97	27	29	59	212	34.7	
1914	75	B&M	.53	.63	1920	16.29	-	-	-	5	5	30.7	B&M
	85	ASCE	.63	.76	1490	11.16	1	-	-	-	1	8.9	B&M
	90	ARA-B	.59	.72	3192	22.57	3	-	1	4	8	35.5	NP
	90	ARA-B	.62	.75	1241	8.77	-	-	-	-	-	0.0	NYO&W
	90	ASCE	.67	.80	1003	7.09	-	-	-	1	1	14.1	P&R
	90	GN	.59	.72	2130	15.06	-	-	-	3	3	19.9	GN
	100	ARA-A	.70	.85	4600	29.20	-	-	-	-	-	0.0	CRRNJ
	100	NYNH&H	.63	.76	1572	10.00	-	-	-	-	-	0.0	B&M
	100	NYNH&H	.63	.76	4838	30.79	-	1	1	3	5	16.2	NYNH&H
	100	P&R	.67	.80	5526	35.16	-	1	-	1	2	5.6	P&R
	100	PS	.62	.75	5288	33.65	7	1	-	6	14	41.6	PRR
	101	DL&W	++	++	4376	27.57	4	7	-	1	12	43.5	DL&W
	105	DL&W	++	++	4513	27.35	3	4	1	-	8	29.2	DL&W
	135	CRRNJ	.90	1.05	1103	5.20	-	-	-	-	-	0.0	CRRNJ
		Totals			42792	279.86	18	14	3	24	59	21.1	
1915	90	ARA-A	.59	.72	1000	7.07	-	-	-	-	-	0.0	CB&Q
	90	ASCE	.67	.80	1996	14.11	1	1	-	2	4	28.3	P&R
	100	"96-A"	.60	.75	3479	22.14	-	-	-	-	-	0.0	CV
	100	ARA-B	.63	.76	1350	8.59	2	1	-	-	3	35.0	Virginian
	100	P&R	.67	.80	5294	33.69	-	-	-	1	1	2.9	P&R
	105	DL&W	++	++	6734	40.81	-	-	-	-	-	0.0	DL&W
		Totals			19853	126.41	3	2	-	3	8	6.3	
1916	100	P&R	.67	.80	4587	29.19	-	-	-	-	-	0.0	P&R
	105	DL&W	++	++	3063	16.56	-	-	-	-	-	0.0	DL&W
		Totals			7650	47.75	-	-	-	-	-	0.0	

++-Note. "Rail rolled under Physical Test, without limits to chemistry except Phosphorus. Carbon of heats accepted in 1913 varied between .60 and .73. Carbon of heats accepted in 1914 varied between .59 and .73."

Table 7, Sheet 19

Total Rail Failures From Date Rolled to October 31st, 1916

Year Rolled	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Tennessee Coal, Iron & Railroad Company													
1911	75	CS	.55	.68	2218	18.82	-	-	-	-	-	0.0	H&TC
	75	CS	.55	.68	2800	23.76	-	-	-	-	-	0.0	ML&T
	75	Dudley			6010	51.00	1	-	-	1	2	3.9	SAL
	80	ASCE	.55	.68	26780	213.03	94	14	32	44	184	86.4	L&N
	80	ASCE	.55	.65	4098	32.59	-	-	-	-	-	0.0	NC&StL
	80	ASCE	.58	.71	7000	55.68	-	2	-	2	4	7.2	CofG
	85	ASCE			4411	33.02	14	-	4	1	19	57.5	AGS
	85	ASCE	.59	.72	11750	87.97	32	12	5	23	72	81.8	StL-SF
	85	ASCE	.59	.72	32093	240.25	119	14	13	27	173	72.0	Southern
	85	ASCE			2477	18.54	5	1	-	6	12	64.7	M&O
	85	ASCE	.55	.68	15000	112.30	3	1	1	-	5	4.4	ACL
	85	ASCE	.55	.65	5985	44.81	1	3	11	10	25	55.8	NC&StL
	85	ASCE	.59	.72	7163	53.63	25	6	11	28	70	130.5	CNO&TP
	90	ARA-A	.63	.76	3117	22.04	7	-	-	1	8	36.3	H&TC
	90	ARA-A	.63	.76	1000	7.07	1	-	-	1	2	28.3	ML&T
	90	ARA-A			3176	22.48	5	-	-	-	5	22.2	SP
	90	ARA-A	.63	.76	8592	60.75	39	8	2	3	52	85.6	IC
	90	ARA-A	.58	.71	3000	21.21	23	1	1	5	30	141.5	CofG
	90	ARA-A	.63	.76	3373	23.85	1	-	-	-	1	4.2	HNO
	90	CS	.63	.76	7415	52.43	44	6	6	17	73	139.2	IC
		Totals			157458	1195.23	414	68	86	169	737	61.7	
1912	75	CS	.55	.68	7323	62.00	-	-	-	1	1	1.6	HE&WT
	75	CS	.55	.68	1123	9.53	-	-	-	-	-	0.0	GH&SA
	75	CS-R	.55	.68	6942	58.90	-	-	-	-	-	0.0	H&TC
	75	CS-R	.63	.76	5423	46.01	-	-	-	-	-	0.0	OSL
	75	CS-R	.55	.68	3000	25.45	-	-	-	-	-	0.0	AE
	80	ASCE	.58	.71	1800	14.32	9	7	3	7	26	181.6	CofG
	80	ASCE	.55	.65	3183	25.32	-	-	-	-	-	0.0	NC&StL
	80	ASCE	.55	.68	10266	81.66	28	7	2	7	44	53.9	L&N
	85	ASCE	.59	.72	22670	169.67	98	16	21	26	161	94.9	Southern
	85	ASCE	.55	.68	11980	89.69	6	2	3	5	16	17.8	ACL
	85	ASCE			1406	10.52	-	-	-	-	-	0.0	GH&H
	85	ASCE	.55	.65	7063	52.88	2	14	4	10	30	56.7	NC&StL
	85	ASCE	.59	.72	5610	42.00	14	2	1	13	30	71.4	StL-SF
	85	ASCE			1000	7.49	4	-	-	2	6	80.0	CNO&TP
	85	ASCE			4836	36.12	3	1	1	6	11	30.4	AGS
	85	Dudley	.62	.75	6128	45.87	1	10	7	11	29	63.2	SAL
	90	ARA-A	.58	.71	2000	14.14	6	1	1	7	15	106.1	CofG
	90	ARA-A			2786	19.70	3	-	2	-	5	25.4	SP
	90	ARA-A	.63	.76	17861	126.29	106	11	142	76	335	265.2	IC
	90	ARA-A	.63	.76	1727	12.21	8	-	-	3	11	90.0	GH&SA
	90	ARA-B	.60	.73	31465	222.47	49	14	4	24	91	40.9	L&N
	90	ASCE	.59	.72	13000	91.92	8	2	3	19	32	34.7	StL-SF
	90	SF	.63	.76	8733	61.75	10	-	-	2	12	19.4	AT&SF
		Totals			177325	1325.91	355	87	193	220	855	64.5	
1913	75	CS-R	.55	.68	1121	9.51	-	-	-	-	-	0.0	H&TC
	75	CS-R	.55	.68	5833	49.49	-	-	-	1	1	2.0	GH&SA
	75	CS-R	.55	.68	2700	22.91	-	-	-	-	-	0.0	AE
	80	ASCE	.55	.66	9251	73.59	6	1	1	3	11	14.9	L&N
	80	ASCE	.55	.65	2438	19.39	-	-	-	-	-	0.0	NC&StL
	80	ASCE	.58	.71	5300	42.16	3	3	-	-	6	14.2	CofG
	85	ASCE	.55	.65	6680	50.00	-	-	1	1	2	4.0	NC&StL
	85	ASCE	.59	.72	26056	195.05	33	6	4	11	54	27.7	Southern
	85	ASCE	.55	.68	14940	111.84	-	3	1	3	7	6.2	ACL
	85	ASCE	.59	.72	5221	39.09	5	1	1	2	9	23.0	AGS
	85	ASCE			3811	28.52	21	3	2	2	28	98.0	CNO&TP
	85	ASCE			1228	9.17	-	-	-	-	-	0.0	M&O
	85	Dudley	.59	.75	11682	87.45	12	-	7	8	27	30.8	SAL
	90	ARA-A	.63	.76	10947	77.40	-	-	-	-	-	0.0	H&TC
	90	ARA-A	.63	.76	36955	261.30	107	5	13	21	146	55.8	IC
	90	ARA-A	.58	.71	2200	15.55	5	-	-	1	6	38.6	CofG
	90	ARA-A	.63	.76	4848	34.28	-	-	-	-	-	0.0	ML&T
	90	ARA-A	.63	.76	8562	60.54	1	-	-	-	1	1.7	GH&SA
	90	ARA-A	.59	.72	3117	22.04	1	-	-	2	3	13.6	MP-IM
	90	ARA-A	.63	.76	7067	50.00	-	-	-	-	-	0.0	T&NO
	90	ARA-B	.63	.76	56719	401.03	48	25	6	35	114	28.4	L&N
	90	ASCE	.55	.65	8063	57.01	-	1	2	2	5	8.8	NC&StL
	90	ASCE	.62	.75	5800	41.01	7	2	-	2	11	26.8	StL-SF
		Totals			240539	1758.35	249	50	38	94	431	24.5	

Table 7, Sheet 20

Total Rail Failures From Date Rolled to October 31st, 1916.

Year Rolled	Lbs Per Yd.	Sec.	Specified Carbon		Total Tons Laid	Equiv. Track Miles	Failures to Date						R. R.
			Min.	Max.			Head	Web	Base	Brkn	Total	Per 100 Trk Mls	
Open Hearth - Tennessee Coal, Iron and Railroad Company - Continued													
1914	80	ASCE	.53	.66	7027	55.90	-	-	-	-	-	0.0	L&N
	80	ASCE	.55	.65	2512	19.97	1	-	-	-	1	5.0	NC&StL
	80	ASCE	.58	.71	4537	36.09	-	-	-	1	1	2.8	CofG .
	85	ASCE	.59	.72	23416	175.22	58	3	3	4	68	38.8	Southern
	85	ASCE	.55	.68	15750	117.91	-	-	-	1	1	0.9	ACL
	85	ASCE	.59	.72	12441	93.14	7	4	-	-	11	11.8	AGS
	85	ASCE			2976	22.28	3	-	-	2	5	22.4	M&O
	85	Dudley	.59	.72	1408	10.61	-	-	-	2	2	18.8	SAL
	90	ARA-A	.59	.72	4427	31.30	-	-	-	-	-	0.0	MP-IM
	90	ARA-A	.63	.76	24684	174.53	50	3	5	9.	67	38.3	IC
	90	ARA-A			6346	44.90	-	-	-	-	-	0.0	SP
	90	ARA-A	.63	.76	2687	19.00	-	-	-	-	-	0.0	LW
	90	ARA-A	.63	.76	2025	14.32	2	-	-	-	2	14.0	H&TC
	90	ARA-A	.63	.76	6237	44.10	-	-	-	-	-	0.0	GH&SA
	90	ARA-B	.63	.76	80914	572.11	68	16	3	14	101	17.7	L&N
	90	ASCE	.62	.75	42430	300.01	5	4	5	18	32	10.7	StL-SF
	90	ASCE	.55	.65	3931	27.78	-	1	-	-	1	3.6	NYC&StL
		Totals			243748	1759.17	194	31	16	51	292	16.6	
1915	80	ASCE	.58	.71	2004	15.94	-	-	-	-	-	0.0	CofG
	80	ASCE	.55	.65	3000	23.87	7	-	1	1	9	37.7	NC&StL
	85	ASCE	.55	.68	6300	47.17	-	-	-	-	-	0.0	ACL
	85	ASCE	.59	.72	24395	182.62	3	1	-	2	6	3.3	Southern
	85	ASCE			1808	13.54	-	-	-	1	1	7.5	M&O
	85	ASCE	.59	.72	2735	20.48	-	-	-	-	-	0.0	AGS
	85	ASCE	.59	.72	3104	23.24	3	-	-	1	4	17.6	CNO&TP
	90	ARA-A	.59	.72	10565	76.82	-	-	-	-	-	0.0	MP-IM
	90	ARA-A	.63	.76	1400	9.90	-	-	-	-	-	0.0	LW
	90	ARA-A	.62	.75	2989	21.13	-	-	-	-	-	0.0	NC&StL
	90	ARA-A	.63	.76	11221	79.34	-	-	-	-	-	0.0	GH&SA
	90	ARA-A	.63	.76	4584	32.41	-	-	-	-	-	0.0	H&TC
	90	ARA-A	.63	.76	3755	26.55	2	1	-	-	3	11.3	IC
	90	ARA-B	.62	.75	39698	280.69	14	5	1	5	25	8.9	L&N
	90	ASCE	.62	.75	20510	145.00	-	2	7	3	12	8.3	StL-SF
		Totals			138368	998.70	29	9	9	13	60	6.0	
1916	80	ASCE	.53	.66	1838	14.62	-	-	-	1	1	6.8	L&N
	85	ASCE	.59	.72	7671	57.28	-	1	-	2	3	5.2	Southern
	85	ASCE	.59	.72	21000	157.22	-	-	-	-	-	0.0	ACL
	85	ASCE	.59	.72	1150	8.68	-	2	-	-	2	23.0	AGS
	85	Dudley	.59	.72	7205	53.94	2	-	-	-	2	3.7	SAL
	90	ARA-A	.63	.76	7681	54.31	-	-	-	-	-	0.0	IC
	90	ARA-A	.59	.72	1141	8.06	-	-	-	-	-	0.0	SAL
	90	ARA-A	.63	.76	13637	96.42	-	-	-	-	-	0.0	GH&SA
	90	ARA-A	.62	.75	6116	43.24	-	-	-	-	-	0.0	NC&StL
	90	ARA-B	.62	.75	39610	280.07	-	8	-	3	11	3.9	L&N
	90	ASCE	.62	.75	15980	113.00	-	1	-	-	1	0.9	StL-SF
		Totals			123029	886.84	2	12	-	6	20	2.3	

INFLUENCE OF GAGE LENGTH ON ELONGATION IN DROP TEST OF RAILS.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

In the drop test of rails it is usual to measure the elongation of the part in tension by marking six spaces of one inch each on the side to be put in tension, and generally the spacing is marked by means of a gang punch of seven prick punches equally spaced with one inch between punch points. The aim is to have the tup strike directly over the center mark and in the ideal case the two spaces next the center would stretch equally and more than the others, the spaces adjacent on each side would stretch equally, and the two end spaces would stretch equally, but less than the others. Of course, in actual practice in the mill, this ideal case is usually only approximated.

The ductility of the rail is usually expressed as per cent. of elongation of the one-inch space which stretched most; and when measured after the rail has received a sufficient number of blows to break it, the ductility is called the exhausted ductility. In some cases the full six inches is taken as the gage length and the ductility expressed as the per cent. of elongation in six inches. The longer gage length has the advantage that an error in measurement is a smaller percentage of the length, although this advantage is frequently nullified by the total length being obtained by adding together the separate lengths of the six spaces. The stretch is not uniform over a length of six inches and therefore a true measurement of ductility is not obtained, whereas with a gage length of one inch a close approximation can be obtained. When successive blows do not strike in just the same place, another variable is introduced which probably tends to increase the measurement of exhausted ductility in the long gage length, but probably does not affect the result when a one-inch length is used. For the measurement it is usual to use a flexible scale laid on the rail, but a closer measurement can be obtained by means of multiplying dividers as illustrated in Figs. 1 and 1′ in Report 61 on Quick Bend Test. (See Proceedings, American Railway Engineering Association, Volume 18, 1917, pages 1107 and 1108.)

The purpose of this study was to determine the difference in the per cent. of elongation when measured in a gage length of six inches as compared with the per cent. in one inch. Some typical drop test results were taken from the published Proceedings of the American Railway Engineering Association as follows: The results on some 100-lb. A. R. A. type B open-hearth rails obtained by the writer and the results on some 100-lb. Dudley section open-hearth rails obtained by Dr. P. H. Dudley. (See Proceedings, American Railway Engineering Association, Volume

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Rail Report 66, August, 1917.

12, Part 2, pp. 442, 443 for the first named results and p. 552 for Dr. Dudley's results.) For convenient reference the figures used are given herewith as table 1. These results are plotted in Fig. 1, to show the relation between the per cent. of elongation in the "longest" inch and six inches, and also the relation between the "longest" and "shortest" inches. The maximum elongation in one inch is plotted horizontally and the elongation in six inches and the minimum in one inch are plotted vertically.

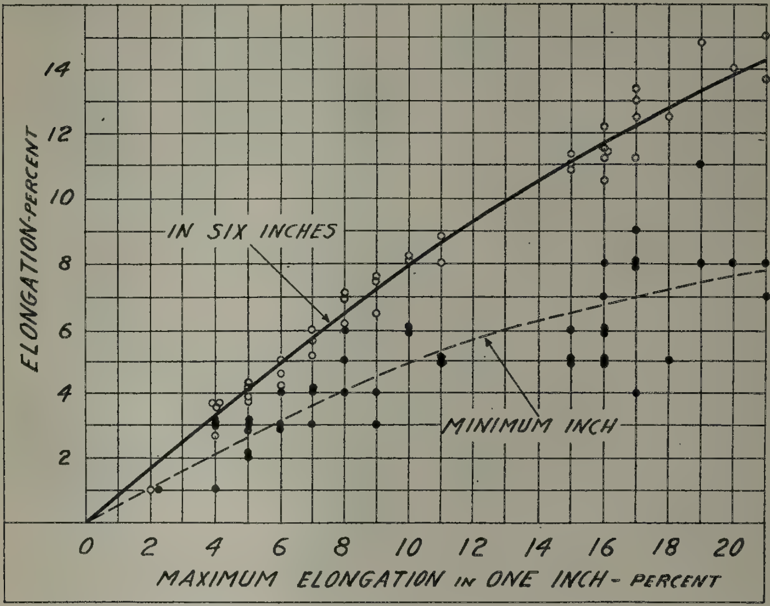


FIG. 1. THE ELONGATION IN THE "LONGEST" INCH AS RELATED TO AVERAGE IN SIX INCHES AND TO "SHORTEST" INCH.

It will be noted from the diagram that an elongation of six per cent. in the maximum inch is equivalent to about 4.9 per cent. over the six inches or an elongation of six per cent. in six inches is equivalent to about 7.3 per cent. in the maximum inch. At these elongations, also, the elongation in the minimum inch is just about half the elongation in the maximum inch. At greater elongations the ratios of the six inch and the minimum elongations to the maximum elongation decrease somewhat.

TABLE 1.—ELONGATION RESULTS.

Test No.	No. of Blow	Elongation—Inches								Remarks
		1	2	3	4	5	6	Total	Average	
				HEAD IN TENSION						
G1A4	1	.02	.03	.04	.03	.03	.01	.16	.027	Broke
G1B4	1	.03	.03	.05	.06	.05	.03	.25	.042	Broke
G1C4	1	.04	.05	.06	.07	.07	.05	.34	.057	
	2	.06	.09	.14	.15	.13	.09	.66	.110	
	3	.08	.13	.18	.19	.16	.11	.85	.142	
	4	.08	....	.17	.19	.16	.11	....	....	Broke
G1D4	1	.03	.04	.06	.07	.06	.05	.31	.052	
	2	.07	.10	.15	.16	.13	.09	.63	.105	
	3	.07	.12	.19	.21	.14	.09	.82	.137	Broke
G1E4	1	.05	.07	.08	.08	.05	.04	.37	.062	
	2	.09	.15	.16	.15	.09	.05	.69	.115	
	3	.10	.17	.21	.21	.13	.08	.90	.150	Broke
G1F4	1	.04	.05	.07	.07	.07	.06	.36	.060	
	2	.05	.08	.12	.16	.16	.12	.69	.115	
	3	.05	.08	.12	.16	.16	.12	.69	.115	Broke
				BASE IN TENSION						
G1A5	1	.00	.01	.02	.01	.01	.01	.06	.010	Broke
G15B	1	.03	.03	.04	.05	.04	.04	.23	.038	
	2	.04	.04	.05	.07	.09	.10	.39	.065	
	3	.06	.08	.12	.15	.15	.12	.68	.113	
	4	.11	.14	.19	.18	.15	.12	.89	.148	Broke
G1C5	1	.03	.03	.04	.04	.04	.04	.22	.037	
	2	.05	.06	.08	.08	.08	.07	.42	.070	
	3	.06	.08	.09	.10	.09	.07	.49	.082	Broke
G1D5	1	.03	.03	.04	.04	.04	.03	.21	.035	
	2	.06	.08	.10	.10	.09	.06	.49	.082	
	3	.11	.15	.17	.16	.11	.08	.78	.130	
	4	.12	....	.20	.19	.13	.08	....	....	Broke
G1E5	1	.04	.05	.05	.05	.04	.03	.26	.043	
	2	.08	.11	.11	.11	.07	.05	.53	.088	
	3	.12	.15	.16	.13	.11	.06	.73	.122	
	4	.12	.16	.17	.15	.12	.08	.80	.133	Broke
G1F5	1	.03	.03	.04	.04	.04	.04	.22	.037	
	2	.05	.05	.07	.11	.11	.09	.48	.080	
	3	.05	.07	.10	.14	.15	.14	.65	.108	
	4	.05	.07	....	.13	.15	.14	....	....	Broke
21596	1	.02	.05	.05	.04	.04	.03	.23	.038	
	2	.06	.07	.08	.08	.07	.06	.42	.070	
	3	.08	.10	.14	.16	.12	.08	.68	.113	
	4	.08	.12	.16	.17	.13	.09	.75	.125	Broke
15557	1	.03	.05	.05	.05	.04	.03	.25	.042	
	2	.10	.10	.09	.08	.05	.03	.45	.075	
	3	.14	.17	.16	.10	.06	.04	.67	.112	
	4	.15	.18	.18	.12	.07	.05	.75	.125	Broke
14719	1	.04	.05	.06	.06	.04	.03	.28	.046	
	2	.04	.05	.06	.06	.05	.04	.30	.050	Broke
16053	1	.02	.04	.04	.05	.04	.02	.21	.035	

TESTS OF MANGANESE STEEL RAILS.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report is a compilation of reports of tests of manganese steel rails furnished by a number of railroads represented on our Rail Committee. The following were the roads that gave the results of their tests or experience:

Baltimore & Ohio Railroad.
Chicago, Burlington & Quincy Railroad.
Chicago, Milwaukee & St. Paul Railway.
Delaware, Lackawanna & Western Railroad.
Norfolk & Western Railway.
Pennsylvania Railroad.
Pittsburgh & Lake Erie Railroad.

Manganese steel is an alloy steel with about 12 per cent. of manganese, which large amount of manganese has the effect of preventing the transformations that occur in ordinary steel where cooling down from high temperatures. In rolled or forged products, it has a high tensile strength and considerable ductility, is difficult to machine, has a high resistance to abrasion, but has a low elastic limit in tensile tests. A general resumé concerning the manufacture and uses of manganese steel has been included by Dr. Hibbard in a dissertation on alloy steels and gives much valuable information, including a bibliography on the subject. (See "Manufacture and Uses of Alloy Steels," by Henry D. Hibbard, Bulletin 100, Bureau of Mines, Washington, 1915, pp. 22-36.) Dr. Henry M. Howe has also given a valuable theoretical discussion of the action of manganese in manganese steel in a paper entitled "The Role of Manganese," before the American Society for Testing Materials in June, 1917.

TEST ON THE BALTIMORE & OHIO RAILROAD.

Information furnished by Earl Stimson, Engineer Maintenance of Way.

On October 22nd, 1912, a test of manganese steel rails was started on the eastbound track at Kessler's Curve, 2½ miles east of Paw Paw Station, on the Cumberland Division. The test was composed of 30 rails each of the following:

Maryland—Bessemer Titanium Rail.
Cambria—Open-Hearth Rail.
Manganese Steel Rail.

Rail Report 67, September, 1917.

The alinement at this point was a 9-degree curve carrying a superelevation of 7½ in., the curve being on a 0.21 per cent. grade, descending in the direction of the traffic.

The object of this test, which was known as Rail Test No. 930, was to determine whether the manganese rail would give such an increased life over the Bessemer and Open-Harth rail that it would be more economical to use at such locations where the curvature is great and the abrasion of ordinary rails so high that their life is only about 1½ to 2 years.

The manganese rails were furnished by the Manganese Steel Rail Company of New York and rolled by the Illinois Steel Company, South Works.

In February, 1914, after 16 months' service, it was necessary to remove all of the low rails in the test, except the manganese rails, on account of cracking under the head. Sections taken on February 12th, 1914, just before these rails were removed, showed that the average per cent. of area abraded to total area of the head was 3.02 per cent. for the manganese high and low rails, 6.45 per cent. for the Cambria Open-Hearth and 13.92 per cent. for the Maryland Bessemer Titanium.

After 19 months' wear it was necessary to remove all the high-side Cambria Open-Hearth rails. At this period the abrasion of the high rails of the Cambria Open-Hearth and Maryland Bessemer rolling were respectively 1¾ and 4¼ times that of the manganese rail.

A second test of manganese rail, known as Rail Test No. 937, was started January, 1915, at the same location, the manganese rail still remaining in its original position. The test was composed of 30 rails each of the following:

Maryland—Bessemer.
Maryland—Open-Hearth.
Manganese.

This test covered a period of 20 months up to August, 1916, when the track was taken up on account of change of alinement.

For the period of 20 months which this test covered the per cent. of abrasion, as compared with the total area of the head, was as follows:

Maryland—Bessemer	2.51 per cent.
Maryland—Open-Hearth	1.87 per cent.
Manganese	1.59 per cent.

The manganese rails have recently been relaid near Gorsuch, Md., on the Baltimore Division, where further test is being conducted.

The results of the tests covering the high rail only are included in Table 1, and below is given the ratio of abrasion as derived from the square inches abrasion per million tons of traffic:

	Sq. In. Abrasion.	*Ratio.*
Manganese	.0037	1.0
Maryland—Bess. Tit.	.0139	3.8
Cambria—O.-H.	.0056	1.5

TABLE 1.—B. & O. R. R.

Kesslers Curve—High Rail Only—Degree of Curve—9°.

LOCATION	KIND OF STEEL	Wt. per yard	Type of Section	CHEMISTRY					Date Laid	Date Removed	Month's Service	Million tons over rail	Abrasion Sq. In.	Abrasion per million tons Sq. In.	REMARKS
				C	P	S	Mn	Si							
Kesslers Curve	Manganese I.. St. Co., South Wks.	100	A. R. A. B.	1.2	0.04 to 0.05	Under 0.01	12.0	0.15	10–22–12	8–25–16	46	96	.357	.0037	Removed account of change of line.
Kesslers Curve	Bess. Tit., Maryland	100	A. B. A. B.	0.502	0.058	0.066	0.96	0.08	10–22–12	2–12–14	16	50	.696	.0139	Chromium0.27 Nickel....80.3
Kesslers Curve	Open-Hearth, Cambria	100	A. R. A. B.	0.76	0.0225	0.0245	0.79	0.091	10–22–12	12– 1–14	25	79	.443	.0056	

It will be noted that the abrasion on the carbon steel rails was somewhat greater than on the manganese, varying from 1.5 times on the Open-Hearth rails to 3.8 times on the Bessemer rails.

TESTS ON CHICAGO, BURLINGTON & QUINCY RAILROAD.

In response to a request for the results of tests of manganese rail, Mr. A. W. Newton, Chief Engineer, forwarded a copy of a report of tests which he made under date of June 26, 1912, of some special rails, among them being some manganese rails. This report, without the diagrams, is copied below:

History.

In 1909 the question of value of certain kinds of metal for the manufacture of rails for use at points where excessive wear occurs was being considered, and after conference with a representative of the Pennsylvania Steel Company, it was decided that a test should be made. Vice-President Willard authorized the purchase of four kinds of rail and a test of same in the "Goose Neck" at Kansas City, Mo., at which point ordinary Bessemer rail only gave a service of from fourteen to eighteen months, and rails were generally changed out in from nine to ten months on outside of curve.

A test is also being conducted at the west end of Plattsmouth Bridge on a 12-degree curve where there is an ascending eastbound grade and monthly density of approximately 446,500 tons.

Kinds of Rail.

All rail was standard 85-lb. American Society of Civil Engineers section. The kinds of rail purchased for this test and their chemical composition are as follows:

Kind of Rail.	Heat No.	Carb.	Phos.	Sulph.	Mang.	Nick.	Chro.
*Ferro-Titanium, Open-Hearth..	9435	0.80	.021	.033	0.74	....	....
Chrome Nickel, " " ...	12455	0.72	.008	.024	0.72	1.60	0.60
High Carbon, " " ...	16428	0.96	.017	.028	0.59	....	....
Manard Steel..................	M5952	....	....	....	....	....	....
	M5953	....	....	....	....	....	....
	M5954	....	....	....	....	....	....
	M5955	....	....	....	....	....	....

*Two percent Ferro-Titanium alloy added in ladle.

Cost of Rail.

The cost of these rails was in excess of that for standard rail (which is $28.00 per ton for Bessemer and $30.00 for Open-Hearth steel) and was as follows:

Ferro Titanium, Open-Hearth....	$ 43.96 per Gross Ton.
Chrome Nickel, Open-Hearth....	52.00 per Gross Ton.
High Carbon, Open-Hearth......	38.10 per Gross Ton.
Manard	104.10 per Gross Ton.

Location.

The location of rails in Kansas City "Goose Neck" is on a double-track reverse, 8 degrees and 9 degrees 10 minutes curve, at a point where eastbound trains are on ascending and westbound trains on descending grade, where the traffic of the Burlington, Alton, Rock Island and Wabash railroads is concentrated.

The rails are subjected to an approximate density of 375,000 tons per month on each track and, having been in service over 2½ years, they have been subjected to a service of at least 11,250,000 tons.

The second test is located, as stated before, at west end of Plattsmouth Bridge on a 12-degree curve, and rails have to date been subjected to a density of traffic amounting to approximately 8,483,500 tons. This track was relaid in August, 1909, with Colorado Fuel & Iron Co.'s Open-Hearth 85-lb. rails, which gave a service of 15 months; and Bessemer rail used prior to that time was replaced every 12 months.

Examination of rails just completed indicates that, while those in the "Goose Neck" are becoming badly worn, they may still be left in track some time without danger to traffic.

The rails in curve at Plattsmouth Bridge are still in good condition, and the time when replacement will be necessary is indefinite, although they have already given a service longer than the Open-Hearth rails preceding same and one and one-half times that of Bessemer rails which were formerly used there.

Various measurements have been made of certain rails in these tests and diagrams are attached showing condition of heads and per cent. of loss by wear at the time of taking measurements.

A summary of the data shown on these diagrams is given herewith:

SUMMARY OF SERVICE OF TEST 85-LB. RAIL.

IN GOOSE NECK, KANSAS CITY.

Metal.	Make.	Curve.	Grade	Percent Loss in Head Area.				Laid.
				9 Mo.	18 Mo.	22 Mo.	29 Mo.	
Bessemer	C.F.& I.	8° and 9° 10′	0.3	19.4	......	......	......	Prior '09
Open-Hearth	C.F.& I.	do	0.3	......	31.2	......	......	" '09
Nickel, Open-Hearth	P.S.Co.	do	0.3	4.2	7.8	11.0	13.7	Dec. '09
F. Titanium, Open-H	P.S.Co.	do	0.3	5.3	9.4	12.6	18.5	" '09
H. Carbon, Open-H	P.S.Co.	do	0.3	7.6	13.3	16.8	17.5	" '09
Manard	P.S.Co.	do	0.3	2.5	8.9	12.5	18.0	" '09
Tonnage Density in Thousands				6750	13500	16500	21750	

AT PLATTSMOUTH BRIDGE.

Metal.	Make.	Curve	Grade	Percent Loss Head Area.			Laid
				10 Mo.	15 Mo.	17 Mo.	
Manard	Penn. S. Co.	12°	0 5	4.8	....	8.2	Nov. '10
Ferro-Titanium, Op.-H	do	12°	0.5	5.8	....	9.8	" '10
Nickel Steel, Op.-H	do	12°	0.5	4.7	....	6.5	" '10
High Carbon, Op.-H	do	12°	0.5	6.6	....	....	" '10
Open-Hearth	C. F. & I. Cl.	12°	0 5	5.4	9.5	11.9	Prior '10
Tonnage Density in Thousands				4465	6698	7593	

In both tests conducted, it will be seen that the nickel steel (Open-Hearth) rails show least wear, the per cent. of wear being 13.7 per cent. for 29 months, as against 18.5 per cent. for Ferro-Titanium (Open-Hearth) and 17.5 per cent. for high carbon (Open-Hearth) rails.

Manard rails show a most unexpected decrease in sectional area, in one case amounting to 8.2 per cent. for 17 months and 18.0 per cent. for 29 months. Diagrams show the extreme distortion occurring to the Manard rails, to which reference will be made under rail failures.

Rail Failures.

In the test in "Goose Neck" at Kansas City, 138 rails were laid and during the 29 months of service 11 rails have failed for various causes.

These rails were classed as follows:

Nickel Steel	1
Manard	2
Ferro-Titanium	7
High Carbon	1

One high carbon rail has failed in test at Plattsmouth Bridge, where 74 rails were laid. Only one rail showed pronounced defect, it being a high carbon rail laid at Plattsmouth Bridge. All other rails broke, and analyses show high carbon content to prevail.

As noted before, the Manard rails show a decided inclination toward distortion of section, and this was particularly the case on inside of curve. Careful examination did not show evidence of wear, so that, with such a decided decrease in head area, it is concluded the metal was compressed into a more dense mass by the loads passing over same. Tests of rails examined showed a surface hardness of 45 to 48, while interior of head only showed 25 to 30. These tests seem to confirm the conclusion as to compression of metal rather than wear.

Observation and Conclusions.

During the life of this test 11 rails have been taken from track because of failure—or one in each 20 rails laid.

Chemical analyses of these rails indicate a carbon content higher than is now considered good practice, as rails having such high carbon fail under the least adverse conditions.

It will also be noted that analyses of six of these failed rails show a higher carbon content than original report of manufacturer indicated:

Kind of Rail.	Carbon Content.	
	Mfrs. Report.	R. R. Co.'s Analyses
Open-Hearth Ferro-Titanium	0.80	0.93
Open-Hearth High Carbon	0.96	0.98 to 1.00
Open-Hearth High Carbon	0.96	0.99 to 1.10
Chrome Nickel	0.72	0.85 to 0.87
Open-Hearth High Carbon	0.96	1.10 to 1.11
Chrome Nickel	0.72	0.90

The high cost of Manard rails is such that, with service obtained, they can hardly be considered an economical proposition, as compared with service obtained from rails of other chemical composition.

It is very evident that their use on lower or inside rails of curves is not warranted, as they become distorted as to section. On outside of curve their service is such that they may be expected to give as long or longer life than any other of the kinds of rail being tested, but not sufficiently increased to equal the great increase in cost.

So far as tests have been conducted, they indicate that carbon content alone does not govern per cent. of wear, as rails in same curve and under same service show a variation in wear which cannot be attributed to their composition alone.

Other chemical contents of metal, as well as nature of traffic over the rail and local physical conditions all influence amount of wear.

Comparison of results obtained must be based on amount of service rail will carry. From the tables given in this report the following statement, based on freight tonnage, has been developed:

PERCENT OF LOSS IN HEAD WEAR PER MILLION TONS.

Kind.	Make.	Carbon Content.	Kansas City.		Plattsmouth Br.	
			Percent of Loss Head Area.	Comparative Loss.	Percent of Loss Head Area.	Comparative Loss.
Bessemer	C.F.& I.	.48– .58	2.87	1.24	....	....
Open-Hearth	C.F.& I.	.58– .68	2.31	1.00	1.57	1.00
Chrome-Nickel, Open-Hearth.	P. S. Co.	.72	0.63	0.27	0.86	0.55
Ferro-Titanium, Open-Hearth.	P. S. Co.	.80	0.85	0.37	1.29	0.82
High Carbon, Open-Hearth	P. S. Co.	.96	0.80	0.35	1.48	0.94
Manard	P. S. Co.	....	0.83	0.36	1.08	0.69

In arriving at "Comparative Loss," standard Open-Hearth rail is used as a basis for determination.

The test conducted at Kansas City, which covers a period of 29 months, indicates that as a general proposition, with increased carbon content comes increased life, and that the proportion of increase is governed by the secondary conditions noted above.

In both tests the steel containing chromium and nickel shows least percentage of loss, and yet the carbon content in this rail is less than in either the Ferro-Titanium or high-carbon Open-Hearth.

Having the comparative wear of the different kinds of rail, there remains the determination of comparative values of such rail, based on wear and cost, and the following table has been developed (again using standard Open-Hearth rail as a basis):

ACTUAL COST AND VALUE OF RAILS BASED ON COMPARATIVE WEAR.

Kind.	Actual Cost.	Comparative Value at	
		Kansas City.	Plattsmouth Bridge.
Bessemer	$ 28.00	$ 24.20	$.....
Open-Hearth	30.00	30.00	30.00
Chrome-Nickel, Open-Hearth	52.00	111.00	54.54
Ferro-Titanium, Open-Hearth	43.96	81.08	36.58
High Carbon, Open-Hearth	38.10	85.71	31.92
Manard	104.10	83.33	43.48

The "Comparative Value" of the various kinds of rail is determined on basis of comparative wear per million tons of freight passing over same.

A very considerable difference is noted in values obtained from test at Kansas City and at Plattsmouth Bridge, but in both cases the nickel steel shows its superiority as regards wear. At prices paid and considerable percentage of wear, the test at Kansas City shows that Manard rail is worth only $83.33 per ton, instead of $104.10, the amount paid. The other three kinds of special rail all show a comparative value in excess of actual cost.

In the Plattsmouth test only the chrome-nickel rail shows a comparative value equal to or greater than actual cost.

The test at Plattsmouth Bridge does not indicate as great an increased service over standard rail as does the one at Kansas City. The reason for this is not plain, but continuance of test at former place may develop results that will more nearly correspond with those just completed at Kansas City.

The test as made shows these special rails have given an increased service equal to, or in excess of their increased cost over standard Open-Hearth rails, and that the use of special rails is justified in the "Goose Neck" at Kansas City, the 12-degree curve at Plattsmouth, or similar localities on the System.

TEST ON CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.

Information furnished by C. F. Loweth, Chief Engineer.

In April, 1910, the 8-degree curve on the westbound track approaching the Mississippi River Bridge at Sabula was laid with manganese steel rail of 85-lb. American Society of Civil Engineers section, manufactured by the Pennsylvania Steel Company; this rail replacing rail of the same section of carbon steel. The renewals of rail on this track and on the corresponding eastbound track have been at intervals of one to one and one-half years. A fair average of the life of Bessemer rails on this curve is probably one and one-half years.

The high rail is still in track (July, 1917), but the low rail was replaced in August, 1916, by a corresponding section of carbon Bessemer rail; the high rail at the present time showing a life of seven years and the low rail at the time of removal of six years. Soon after this manganese steel rail was laid some difficulty was encountered in keeping it in satisfactory line and surface, as a number of kinks developed, apparently on account of the natural unequal bearing which rails necessarily have in track. The manganese rails apparently molded themselves to the defective bearing instead of springing back to straight lines, as ordinary rails do.

As time went on these faulty conditions increased, being more pronounced on the low rail, but at the same time the rails seemed to show little wear from abrasion. These defects became so bad about a year ago that it was deemed unsafe to retain the low rail in track any longer, especially as it began to show considerable battering at the joints. None of these rails were ever taken out of track on account of wear, but a number of them for other reasons, including eight which were removed on account of cracks developing in the head. These cracks were vertical, extending through the head and slightly into the web of the rail. The rail, however, showed considerable distortion from the original section.

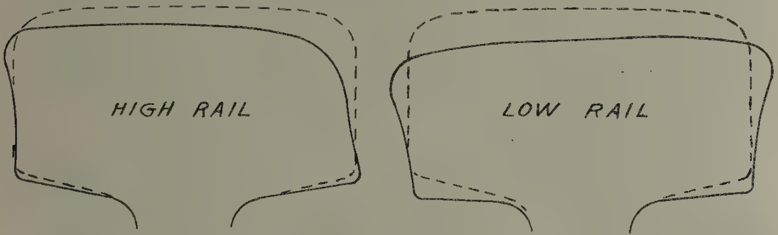


FIG. 1—SECTIONS OF 85-LB. MANGANESE STEEL RAILS ON EAST APPROACH OF SABULA BRIDGE ON 8° CURVE. ORIGINAL SECTIONS ARE SHOWN IN DOTTED LINES.

Fig. 1 shows copies of contour cards taken November, 1915, about 5½ years after the rails were laid. This shows the deformation from the original section, especially with the low rail, the fishing angle being almost at right angles to the axis of the rail. The annual tonnage carried by this rail is four million tons.

TESTS ON DELAWARE, LACKAWANNA & WESTERN RAILROAD.

Information furnished by G. J. Ray, Chief Engineer.

In the fall of 1912, five hundred tons of 101-lb. rolled manganese rail were secured, manufactured at the South Works of the Illinois Steel Company, for use on some of the sharp curves of the eastbound track, one and a half per cent. grade, down the Pocono Mountains. This purchase was made on the strength of the excellent showing made by ten 85-lb. rails made at Passaic, N. J., and tested out on the same track, laid in 1908.

After the manganese rail had been in service for about two years, the low rail on some of the sharpest curves showed signs of flowing. This flowing was not by the formation of a lip, as is usually the case with Bessemer or Open-Hearth rail, but the head of the low rail dished slightly and the entire head seemed to move both ways from the center. With a view of getting the full life out of this rail, we decided to remove the low rail from the curves in question and lay it on the high side of other curves, laying frictionless rail on the low side.

The results of the tests of various rails, including manganese rails, on Cresco, Paradise Tunnel Cut and Analomink Curves, are given in Table 2. The rail indicated as "L. B. F. T." in the seventh column is Lackawanna Bessemer Ferro-Titanium. "L. O. H. S. P." is for Lackawanna Open-Hearth Special Premium. This was a high-carbon rail, treated with Ferro-Titanium, on the recommendation of the manufacturer that the rail would be a good wearing and safe rail. This rail proved to be very brittle and developed transverse fissures and longitudinal seams in the head. Exactly the same thing can be said concerning the Bethlehem Open-Hearth Special Premium, which was purchased under similar condition from the Bethlehem Steel Company. Mention should also be made of the fact that the Bethlehem Open-Hearth 91-lb. rail, rolled in 1908, was a very much harder rail than would be expected from the analysis shown under "Chemistry." As a matter of fact, the most of this rail averaged above .80 in carbon, as the analysis shown in the table is in all cases the reported analysis at the time of rolling and does not anywhere near represent the facts with respect to the Bethlehem 91-lb. rail rolled in 1908. This rail proved to be a very good wearing rail on account of the high carbon, but on the other hand, so many transverse fissures developed that the rail had to be removed from service before it was worn out. Diagrams showing the wear of the rail in the several tests are shown in Figs. 2, 3, 4 and 5. For convenient study, the results of the several tests showing the abrasion of the high rail per million tons of traffic are given below:

HIGH RAILS.

Curve.	*Kind.*	*Sq. In. Abrasion per Million Tons.*
6°	Beth. O.-H.	.0230
6°	Lack. Bess. F. T.	.0283
6°	Lack. O.-H. Spec. Prem.	.0274
6°	Beth. O.-H. Spec. Prem.	.0200
6°	Ill. Manganese	.0035
6°	Ill. Manganese	.0035
6°	Lack. O.-H. Spec. Prem.	.0222
6°	Ill. Manganese	.0034
7°	Lack. Bess.	.0718
7°	Lack. O.-H.	.0583
7°	Passaic Manganese	.0115
7°	Beth. O.-H.	.0275

TABLE 2.

D. L. & W. R. R.
RAIL SERVICE ON CRESCO, TUNNEL CUT AND ANALOMINK CURVES.

Name of Curve or Location	Alignment	Grade	Super-Elevation	Track		Rail			Chemistry. Average of Entire Rolling					Date Rolled	Date Laid	Date Removed	Mos. in Service	Date of Last Section	Kind of Rail Opposite	Mos. in Service to date of Last Section	Millions Tons over Rail	Area abraded in Sq. ins.	Area Abraded per Mill Tons. Sq. ins	Specification Carbon & Mang.	No. of Section	Remarks.
					High or Low	Kind	Wt.	Sec.	Car.	Mang	Phos.	Sil	Sul.													
Cresco	6°00'	-78'	6"	E.B.	H.	B.O.H.	91	D.L.&W.	.688	801	.028	.102	.051	3-08	4-08	11-09	19	11-08	B.O.H.	8	10	0.23	0.023	C.70-83 M.75-100	C-1	
"	"	"	"	"	L.	B.O.H.	91	"	"	"	"	"	"	3-08	4-08	11-09	19	11-08	B.O.H	8	10	0.09	0.009	C.70-83 M.75-100	C-2	
"	"	"	"	"	H.	L.B.F.T.	91	"	.51	.95				9-09	11-09	6-11	19	4-23-10	L.B.F.T.	5	6	0.17	0.0283	C.70-83 M.60-90	C-3	
"	"	"	"	"	H	L.O.H.S.P.	101	"	.843	.89	.025	.119	.034	3-11	6-11	11-12	17	11-12	L.O.H.S.P.	17	23	0.63	0.0274	C.75-90 M.	C-4	
"	"	"	"	"	L.	L.O.H.S.P	101	"	"	"	"	"	"	3-11	6-11	11-12	17	11-12	L.O.H.S.P.	17	23	0.35	0.0152	C.75-90 M.	C-5	
"	"	"	"	"	H	B.O.H.S.P.	101	"	.846	.88	.026	.112	.033	3-11	6-11	11-12	17	11-12	B.O.H	17	23	0.46	0.0200	C.80-90 M	C-6	
"	"	"	"	"	L	B.O.H.S.P.	101	"	.846	.88	.026	.112	.033	3-11	6-11	11-12	17	11-12	B.O.H.S.P.	17	23	0.33	0.0143	C.80-90 M.	C-7	
"	"	"	"	"	H	Ill. St. Co. Mang.	101	"	1.11	12.36	.056	—	.018	10-12	11-12	In Service	57	5-17	Barbey Frict.	55	91	0.32	0.0035	C. M.10-14.	C-8	
"	"	"	"	"	H	Ill. St. Co. Mang	101	"	1.11	12.36	.056	—	.018	10-12	11-12	In Service	57	5-17	Ill. St. Co. Mang.	55	91	0.32	0.0035	C M.10-14	C-9	
"	"	"	"	"	L	Ill. St. Co. Mang.	101	"	1.11	12.36	.056	—	.018	10-12	11-12	In Service	57	5-17	Ill. St. Co. Mang.	55	91	0.31	0.0034	C. M.10-14	C-10	
"	"	"	"	"	L	Barberry Frict.	92	"	.66	.71	.014	.120	.039	4-14	7-14	1-17	30	11-16	Ill. St. Co. Mang.	28	49	0.56	0.0114		C-11	
Paradise Tunnel Cut	6°00'	-78'	6"	E.B.	H	L.O.H.S.P.	101	"	.843	.89	.025	.119	.034	3-11	4-11	10-12	17	10-12	L.O.H.S.P.	18	26	0.58	0.0222	C.75-90 M.	P-1	
"	"	"	"	"	L	L.O.H.S.P.	101	"	"	"	"	"	"	3-11	4-11	10-12	17	10-12	L.O.H.S.P.	18	26	0.40	0.0154	C.75-90 M.	P-2	
"	"	"	"	"	H.	Ill. St. Co. Mang.	101	"	1.11	12.36	0.56		0.18	10-12	11-12	In Service	57	5-17	Barbey Frict.	54	88	0.30	0.0034	C. M.10-14	P-3	
"	"	"	"	"	L	Barberry Frict.	92	"	.66	.71	.014	.120	.039	4-14	9-14	5-17	32	5-17	Ill. St. Co. Mang.	32	52	0.72	0.0138		P-4	
Analomink	7°00'	-78'	7"	E.B.	H	Lack. Bess.	90	"						1907	10-07	7-08	9	7-08	Bess.	9	11	0.79	0.0718		A-1	
"	"	"	"	"	H.	L.O.H.	91	"	.63	.80	.025	.125	.040	1908	7-08	9-10	26	11-08	L.O.H.	4½	6	0.35	0.0583	C.67-80 Av.-70 M.80-105	A-2	
"	"	"	"	"	H	Passaic Mang.	85	Pass. St. Co.						1908	12-08	12-11	36	11-11		36	47	0.54	0.0115		A-3	
"	"	"	"	"	H	B.O.H.	91	D.L.&W.	.736	.87	.026	.164	.041	1910	9-10	12-11	19	12-11	B.O.H.	15	20	0.55	0.0275	C.67-80 M.80-105	A-4	

Note - Analomink Curve Abandoned in 1911, account of relocation of Line

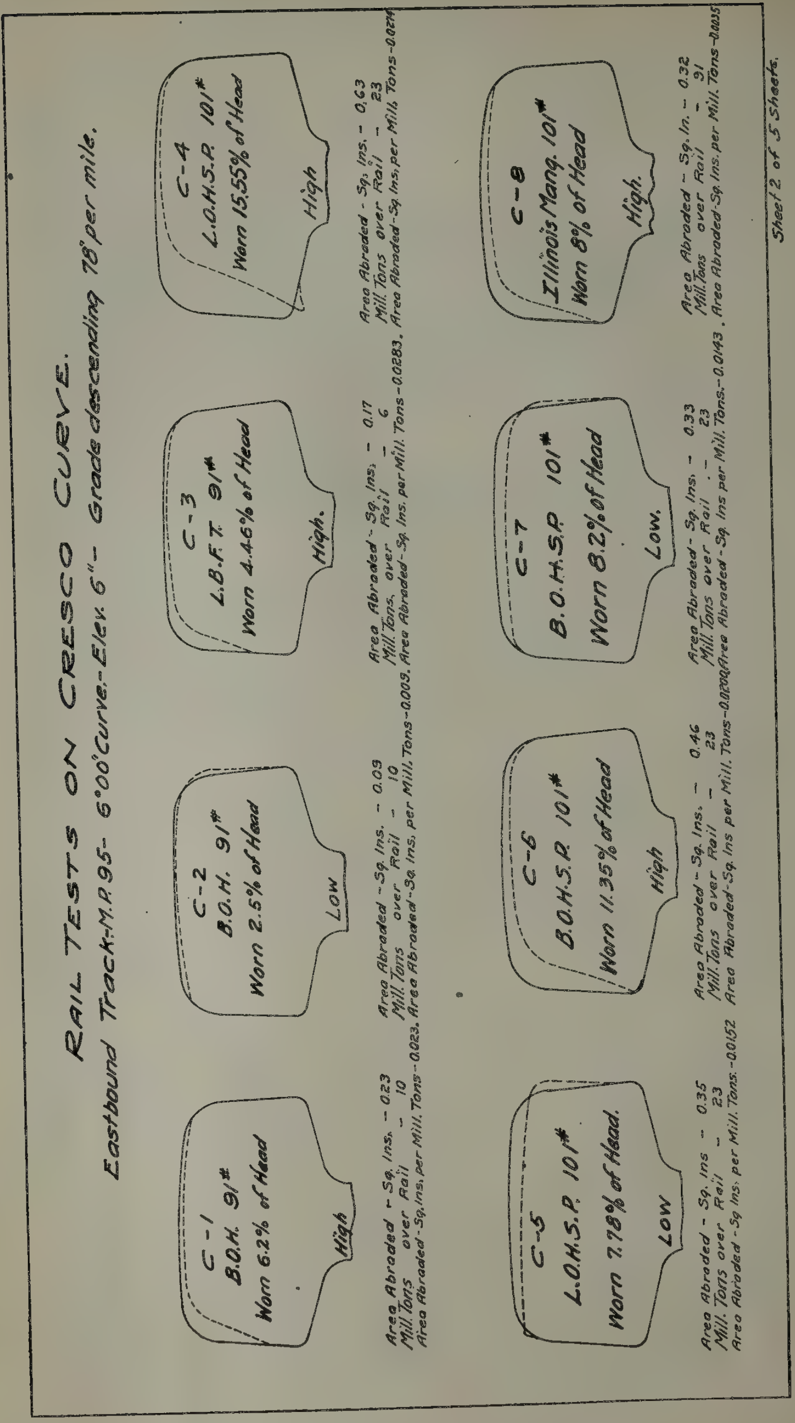

RAIL TESTS ON CRESCO CURVE.
Eastbound Track:-M.P. 95- 6°00' Curve.-Elev. 6"- Grade descending 78' per mile.
C-1
B.O.H. 91#
Worn 6.2% of Head
High
Area Abraded - Sq. Ins. - 0.23
Mill. Tons over Rail - 10
Area Abraded-Sq. Ins. per Mill. Tons-0.023.
C-2
B.O.H. 91#
Worn 2.5% of Head
Low
Area Abraded - Sq. Ins. - 0.09
Mill. Tons over Rail - 10
Area Abraded-Sq. Ins. per Mill. Tons-0.009.
C-3
L.B.F.T. 91#
Worn 4.46% of Head
High.
Area Abraded - Sq. Ins. - 0.17
Mill. Tons, over Rail - 6
Area Abraded-Sq. Ins. per Mill. Tons-0.0283.
C-4
L.O.H.S.P. 101#
Worn 15.55% of Head
High
Area Abraded - Sq. Ins. - 0.63
Mill. Tons over Rail - 23
Area Abraded-Sq. Ins. per Mill. Tons-0.0274
C-5
L.O.H.S.P. 101#
Worn 7.78% of Head.
Low
Area Abraded - Sq. Ins - 0.35
Mill. Tons over Rail - 23
Area Abraded-Sq. Ins. per Mill. Tons.-0.0152
C-6
B.O.H.S.P. 101#
Worn 11.35% of Head
High
Area Abraded - Sq. Ins. - 0.46
Mill. Tons over Rail - 23
Area Abraded-Sq. Ins per Mill. Tons-0.0200
C-7
B.O.H.S.P. 101#
Worn 8.2% of Head
Low.
Area Abraded - Sq. Ins. - 0.33
Mill. Tons over Rail - 23
Area Abraded-Sq. Ins per Mill. Tons.-0.0143.
C-8
Illinois Mang. 101#
Worn 8% of Head
High.
Area Abraded - Sq. In. - 0.32
Mill. Tons over Rail - 91
Area Abraded-Sq. Ins. per Mill. Tons-0.0035
Sheet 2 of 5 Sheets.

FIG. 2.

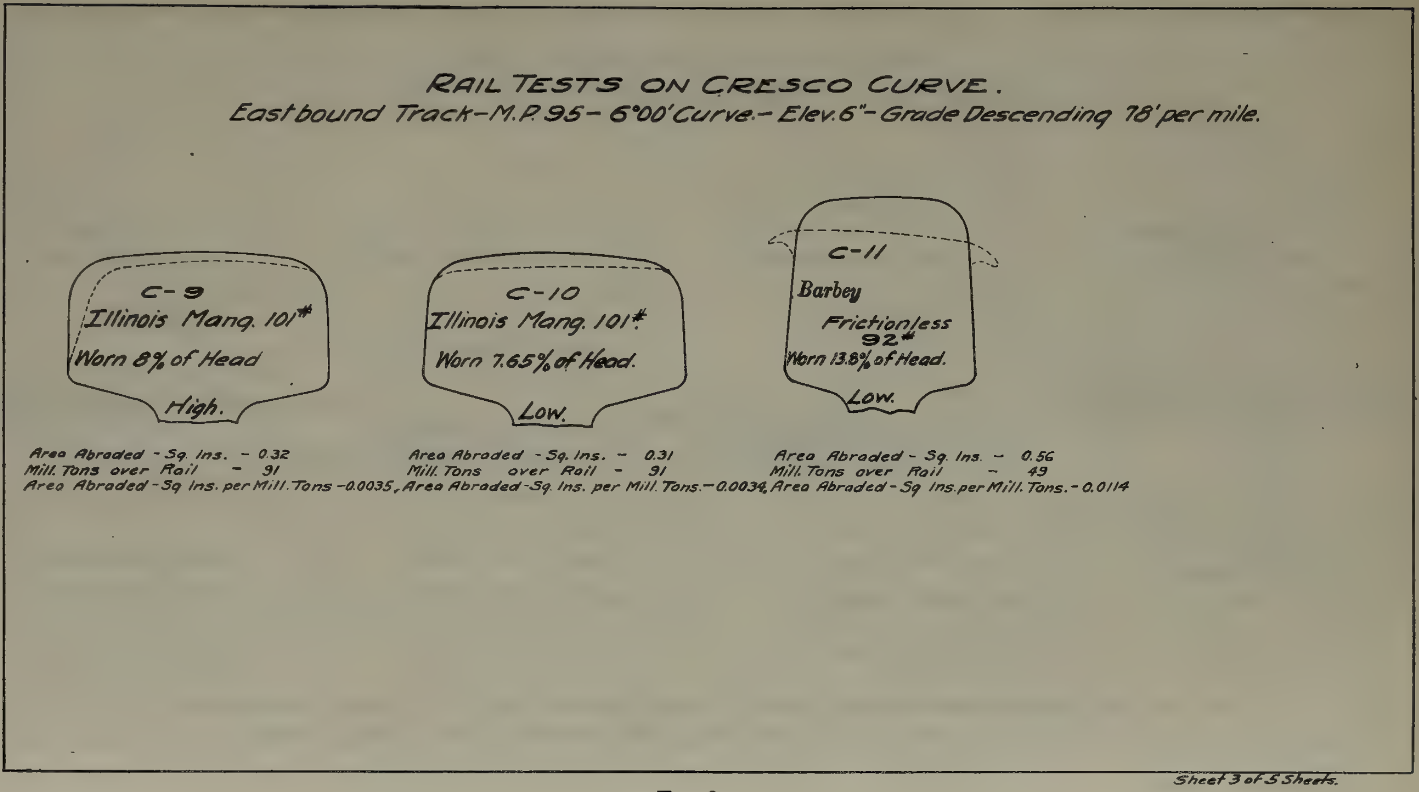

RAIL TESTS ON CRESCO CURVE.
Eastbound Track-M.P. 95-6°00' Curve.-Elev. 6"-Grade Descending 78' per mile.
C-9
Illinois Mang. 101#
Worn 8% of Head
High.
C-10
Illinois Mang. 101#.
Worn 7.65% of Head.
Low.
C-11
Barbey
Frictionless
92#
Worn 13.8% of Head.
Low.
Area Abraded - Sq. Ins. - 0.32
Mill. Tons over Rail - 91
Area Abraded - Sq Ins. per Mill. Tons -0.0035,
Area Abraded - Sq. Ins. - 0.31
Mill. Tons over Rail - 91
Area Abraded - Sq. Ins. per Mill. Tons.-0.0034,
Area Abraded - Sq. Ins. - 0.56
Mill. Tons over Rail - 49
Area Abraded - Sq Ins. per Mill. Tons.-0.0114
Sheet 3 of 5 Sheets.

FIG. 3.

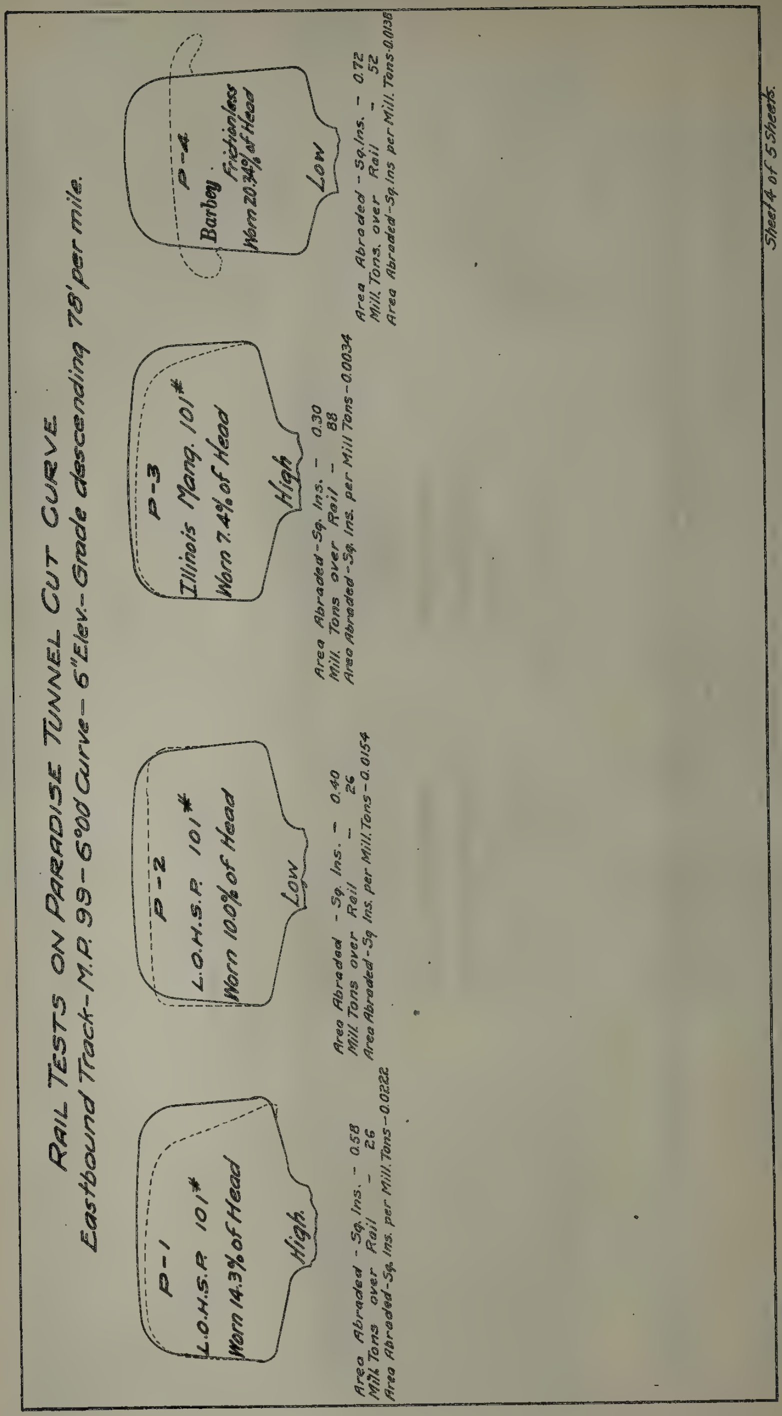

RAIL TESTS ON PARADISE TUNNEL CUT CURVE
Eastbound Track-M.P. 99-6°00' Curve-6" Elev.-Grade descending 78' per mile.
P-1
L.O.H.S.P. 101*
Worn 14.3% of Head
High
Area Abraded - Sq. Ins. - 0.58
Mill. Tons over Rail - 26
Area Abraded-Sq. Ins. per Mill. Tons-0.0222
P-2
L.O.H.S.P. 101*
Worn 10.0% of Head
Low
Area Abraded - Sq. Ins. - 0.40
Mill. Tons over Rail - 26
Area Abraded-Sq. Ins. per Mill. Tons-0.0154
P-3
Illinois Mang. 101*
Worn 7.4% of Head
High
Area Abraded-Sq. Ins. - 0.30
Mill. Tons over Rail - 88
Area Abraded-Sq. Ins. per Mill Tons-0.0034
P-4
Barbey.
Frictionless
Worn 20.34% of Head
Low
Area Abraded - Sq. Ins. - 0.72
Mill. Tons. over Rail - 52
Area Abraded-Sq. Ins per Mill. Tons-0.0138
Sheet 4 of 5 Sheets.

FIG. 4.

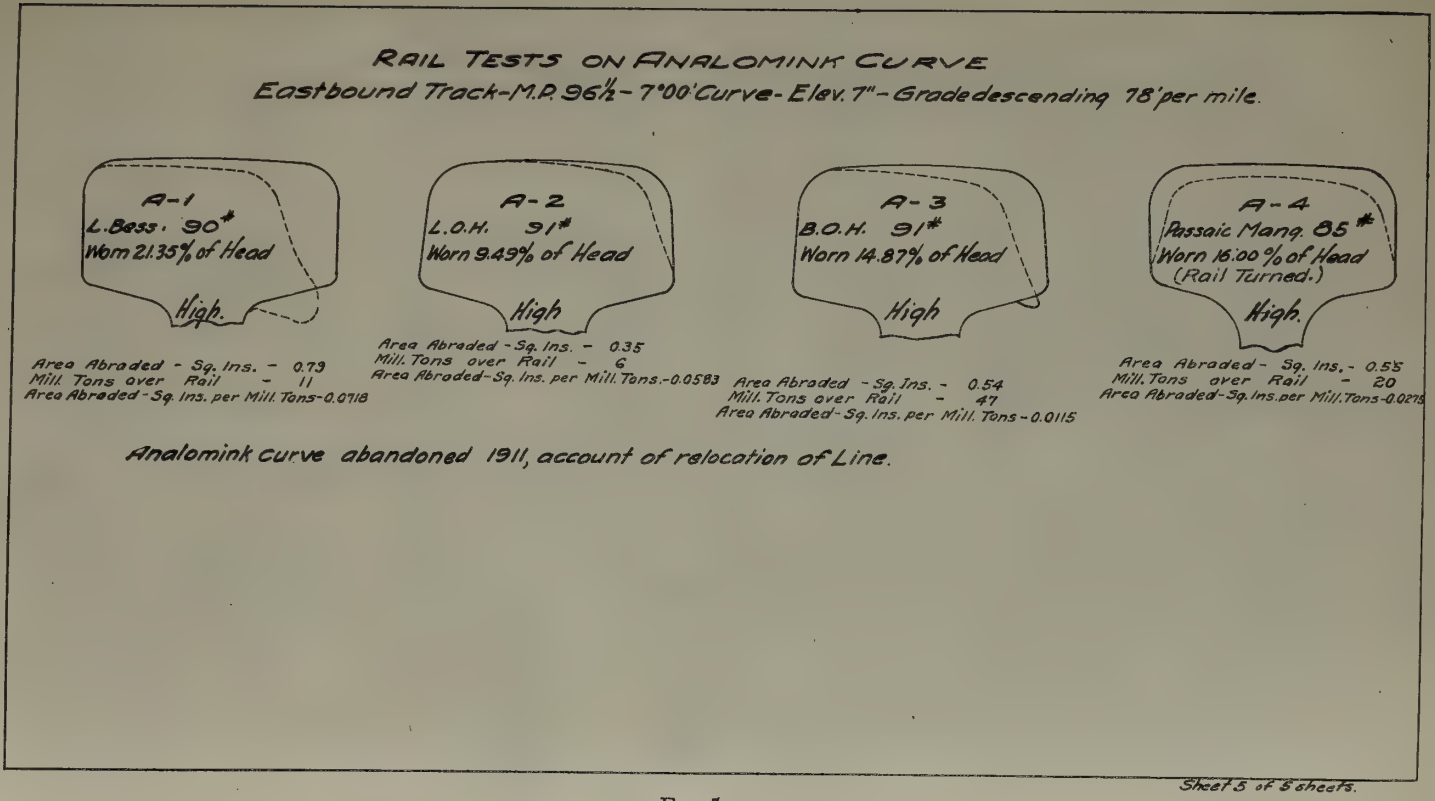

RAIL TESTS ON ANALOMINK CURVE
Eastbound Track-M.P. 96½-7°00′Curve-Elev. 7″-Grade descending 78′ per mile.
A-1
L.Bess. 90#
Worn 21.35% of Head
High.
Area Abraded - Sq. Ins. - 0.79
Mill. Tons over Rail - 11
Area Abraded - Sq. Ins. per Mill. Tons-0.0718
A-2
L.O.H. 91#
Worn 9.49% of Head
High
Area Abraded - Sq. Ins. - 0.35
Mill. Tons over Rail - 6
Area Abraded - Sq. Ins. per Mill. Tons.-0.0583
A-3
B.O.H. 91#
Worn 14.87% of Head
High
Area Abraded - Sq. Ins. - 0.54
Mill. Tons over Rail - 47
Area Abraded - Sq. Ins. per Mill. Tons - 0.0115
A-4
Passaic Mang. 85#
Worn 16.00% of Head
(Rail Turned.)
High.
Area Abraded - Sq. Ins. - 0.55
Mill. Tons over Rail - 20
Area Abraded - Sq. Ins. per Mill. Tons-0.0275
Analomink curve abandoned 1911, account of relocation of Line.
Sheet 5 of 5 sheets.

FIG. 5.

TESTS ON NORFOLK & WESTERN RAILWAY.

Information furnished by Chas. S. Churchill, Assistant to President.

Some tests of manganese rail were made by the Norfolk & Western Railway Company between the dates of April 1, 1909, and September 22, 1916, on curves at Glen Lyn and Goodwin, and recently the tests had to be terminated on account of track changes at those places. The manganese rail were furnished by the Manganese Steel Company. The first lot tested at Glen Lyn consisted of ten rails made at Passaic, N. J., and six of these were removed from track on account of breaking. The breakage was explained as due to improper heat treatment, which was later corrected. (In the manufacture of manganese steel rails it is necessary to quench them immediately after rolling, while still hot, and it is presumed the temperature of these rails was too low or too irregular when quenched.)

The second lot tested at Goodwin consisted of six rails made at the South Works of the Illinois Steel Company, and these remained in service until it was necessary to discontinue the test. The test at Glen Lyn was on the high side of a 9-degree curve, eastbound track, mile post 340.2. The test at Goodwin was on the high side of a 10-degree curve, single track, mile post 313.93.

The results of the tests are shown in Table 3, and below are copied the figures showing the square inches abrasion per million tons of traffic over the rails:

	Square Inch Abrasion.		Ratio.	
	Glen Lyn.	Goodwin.	Glen Lyn.	Goodwin.
Manganese Rails	.0039	.0030	1.0	1.0
Bessemer-Carnegie	.0344	.....	8.8	....
Open-Hearth Bethlehem	.0096	.0084	2.5	2.8
Open-Hearth Carnegie	.0253	.0069	6.5	2.3
Open-Hearth Carnegie	.0100	.0191	2.6	6.4

It will be noted that the abrasion was considerably greater on the carbon steel rails, varying from 2.3 times in one lot of Open-Hearth rails to 8.8 times in the lot of Bessemer rails.

TESTS ON PENNSYLVANIA RAILROAD.

Information furnished by A. W. Gibbs, Chief Mechanical Engineer and
Chairman of the Pennsylvania Railroad System Rail Committee, from reports made October 31, 1916.

Rolled Manard Rail.

On April 28, 1912, about 41 tons (0.27 track miles) of 100-lb. P. S. Manard rails were laid in eastward freight track on the Horseshoe Curve, and Open-Hearth rail was laid simultaneously, adjoining it, for comparison. The Manard rail cost $94.00 per ton. In Septem-

TABLE 3.

Results of Tests on Norfolk & Western Ry.

LOCATION	KIND OF STEEL	Wt. per yard	Type of Section	CHEMISTRY					Date Laid	Date Removed	Months Service	Million tons over rail	Abrasion Sq. In.	Abrasion per million tons Sq. In.	REMARKS
				C	P	S	Mn	Si							
Glen Lyn	Manganese	85	A. S. C. E.	.77	.06	.038	9.93	.25	4– 1–09	....	85	128	.50	.0039	In Service 5-1-16
Glen Lyn	Bess-Carnegie	85	A. S. C. E.	.49	.093	.040	.90	.10	4– 1–09	10–15–10	18.5	24	.825	.0344	
Glen Lyn	Op.-Hth., Bethlehem	85	A. S. C. E.	.684	.026	.038	.737	.138	10–15–10	11–15–13	37	50	.480	.0096	
Glen Lyn	Op.-Hth., Carnegie	85	A. S. C. E.	.67	.010	.032	.72	.138	11–15–13	6–30–15	19.5	30	.76	.0253	
Glen Lyn	Op.-Hth., Carnegie	100	A. R. A. B.	.679	.019	.037	.728	.138	6–30–15	....	10	24	.24	.0100	In Service 5-1-16
Goodwin	Manganese	85	A. S. C. E.	1.03	.060	.024	11.50	.066	1–30–12	9–22–16	56	136	.41	.0030	
Goodwin	Op.-Hth., Bethlehem	85	A. S. C. E.	.702	.027	.032	.730	.133	1–30–12	5– 1–13	16	31	.26	.0084	
Goodwin	Op.-Hth., Carnegie	85	A. S. C. E.	.64	.027	.040	.077	.180	5– 1–13	July, 1915	26	61	.42	.0069	
Goodwin	Op.-Hth., Carnegie	85	A. S. C. E.	.681	.023	.041	.756	.147	July, 1915	9–22–16	15	44	.84	.0191	

ber, 1912, the Open-Hearth was replaced with new Open-Hearth, this latter rail remaining in track until January 7, 1913.

The Open-Hearth rail was again renewed June 20, 1913, and both Open-Hearth and Manard were removed October 15, 1913, the life of the Manard being 17½ months, or four times that of the Open-Hearth.

The figures below give the average abrasion of each kind of rail:

Date of Measurement	Manard.		Open-Hearth.	
	Square Inches.	Percent of Head Abraded.	Square Inches.	Percent of Head Abraded.
October, 1912...............	0.08	1.9	0.52	12.4
February, 1913..............	0.47	11.2	1 25	29.8
June, 1913..................	0.63	15.0	2.11	50.1
October, 1913...............	0.81	19.2	3.11	74.0

There were three failures of the Manard rail out of a total of 84 rails laid, two consisting of transverse fractures through the head and about two-thirds of the web and one by split head.

On January 26, 1914, about 0.27 track miles of Manard rail was laid in the eastward freight track on the Horseshoe Curve in comparison with ordinary Open-Hearth rail. It was removed November 9, 1915, the abrasion being as follows:

Abrasion.	*Manard.*	*Open-Hearth.*
Total area—sq. in..................	0.74	4.13
Per year of service................	0.42	2.35
Per ten million tons of traffic.....	0.07	0.41

On the Middle Division, in 1914, 0.40 track miles of Manard rail was laid, as follows:

Date.	*Miles.*	*Track.*	*Location.*	*Curve.*
Jan. 14	0.16	Ewd. Pass.	W. of Barree	6°
Jan. 26	0.19	Ewd. Pass. & Frt.	E. of Tyrone Forge	6°
May 1	0.05	Ewd. Pass. & Frt.	W. of Shoenberger	6°

This rail is still in track and the stretches west of Barree and east of Tyrone Ford now show wear as follows:

Location.	*Deg. of Curve.*	*Per Cent. of Head Abraded.*	*Service to Date.*	*Life of Ordinary Rail.*
Barree	6°	8.44	33 mos.	14 mos.
Tyrone Forge	6°	10.39	33 mos.	18 mos.

Of the 0.94 track miles of Manard rail in track there have been 40 failures, of which 28 were transverse fractures through the head and a portion of the web, 6 were split head and 6 split web. In no case was the rail broken through. Forty failures in 0.94 track miles in an average life of 3½ years amounts to 1,216 failures per year per 100 miles of track, as compared with an average of 27 failures for all rail on the P. R. R. on the same basis.

A comparison of failures per 100 track miles of Manard rail with those of ordinary Open-Hearth 1913 100-lb. P. S. rails shows the following:

	Failures per 100 Track Miles.				*Position in Ingot.*			
	Head.	*Web.*	*Base.*	*Broken.*	*A.*	*B.*	*L/3.*	**Total.*
Manard	639	639	..	2977	2127	1488	74	4255
Ordinary O.-H...	31	27	2	28	23	16	12	88

*Failures in lower positions divided by 3 to show approximate number in each position.

The annual cost per ton of Open-Hearth rail at $30, lasting one year, is $28, and Manard at $94, lasting four years, is $27. It would therefore be economical to use Manard rail on sharp curves under heavy traffic where ordinary Open-Hearth rail lasts one year or less, but not elsewhere. In this comparison failures are not taken into account. If they are considered, the cost of the Manard rail per ton per year would be increased about $3, and with such a failure rate, would be economical only at locations where ordinary Open-Hearth wears out in 8 months.

Rolled Manganese Rail.

In October, 1915, 104 tons of manganese 100-lb. P. S. rail was purchased from the Manganese Steel Rail Company at $80.00 per ton, with an additional charge for bond holes of 25 cents each and freight to Pittsburgh of $2.94 per ton. The specified composition was carbon, 0.95 to 1.35; manganese, 10.50 to 15.00; phosphorus, not over 0.10.

0.46 track miles was laid in the eastward freight track on the Horseshoe Curve November 9, 1915, and 0.15 track miles in the southward track on Shaw Run Curve, Bellwood Division, May 31, 1916.

In both cases the manganese rail was laid entirely around the curve as a measure of economy, so that no direct comparison with ordinary rail is available; records of wear on both curves are being kept, however.

The abrasion of the rail on the Horseshoe after one year's service was 0.34 sq. in. or 0.09 sq. in. per 10 million tons traffic, as compared with 0.07 sq. in. per 10 million tons traffic for the Manard rail, which was in the same track from January 26, 1914, to November 9, 1915.

One failure has occurred in the manganese rail—a broken rail from "A" position in ingot.

TEST ON PITTSBURGH & LAKE ERIE RAILROAD.

Under date of August 1, 1917, Mr. J. A. Atwood, Chief Engineer, furnished the following information concerning manganese rails tested on the Pittsburgh & Lake Erie Railroad:

We have 86 tons of manganese rails in use on 10-degree curve at Belle Vernon Junction on our road. These manganese rails were placed in November and December, 1913, and March, 1914. They have been in continuous use since and show very little wear. Ordinary rails wear out entirely after 3 to 18 months' wear.

We have taken out one broken rail, but immediately replaced it after we had it drilled and applied angle bars.

Recently we have taken out six other rails which show cracks; some of them almost entirely through the rails. We intend to have these rails drilled and angle bars applied and the rails replaced.

CONCLUSIONS.

The following are probably the conclusions that may be drawn from the various tests described above as made on a number of roads:

1. Manganese steel rails abrade much slower than Bessemer or Open-Hearth steel rails on sharp curves. On curves of 8 or 9 degrees, the abrasion of the high rail per million tons of traffic, as gathered from the above reports, may be taken very roughly, as follows: Manganese, .004 sq. in.; Open-Hearth, .012 sq. in.; Bessemer, 0.20 sq. in. In other words, the abrasion of Open-Hearth rails is about three times that of the manganese rails, and the abrasion of the Bessemer rails is about five times. The results, however, vary considerably and are probably dependent upon the nature of the rolling equipment as well as the tonnage. We also have no information as to relation between the abrasion and degree of curvature.

2. Manganese steel rails become distorted by spreading and drooping of the head more easily than Open-Hearth rails, and apparently, also, than Bessemer rails, explained presumably by the low elastic limit of manganese steel.

3. The failures or breakages of manganese rail were extremely high and seemed to consist mostly of transverse cracks in the head, starting from the surface, resulting finally in pieces of the head breaking out. The manufacturers explain these failures as due to faulty manipulation in the early manufacture of manganese rails, which has since been remedied. Immediately after rolling, while still very hot, it is necessary to quench the rails in water, which operation was not at first handled in an entirely satisfactory manner.

THE RAIL FAILURE SITUATION.

Discussion by C. W. Gennet, Jr., of M. H. Wickhorst's Paper Printed in Bulletin 195, March, 1917.

Mr. Wickhorst's paper, entitled "The Rail Failure Situation," comprises an interesting summary of the principal classes of failed rails. It is also important because of the remedies which the author suggests for the causes of the different types of failures discussed. It would be surprising, however, if, with so broad a subject, some disagreement with the author's ideas and suggestions did not result, and I venture to direct attention, first, to the class of failures described as "Broken Rails," and second, to some matters under the general heading of "Remedies."

In Mr. Wickhorst's opinion, "broken rails," i. e., those failures showing a vertical or angular fracture throughout the section, are intimately associated with seams existing in the base of the rails. While such a condition is without question a common one, still it is entirely too general an explanation and certainly fails to account for a great many failures in rails, the bases of which are free of seams. "Broken rails" are sometimes hard to detect from others whose ultimate failure is due, as Mr. Wickhorst says, to a piece of flange breaking out. Therefore, confusion of two different kinds of square or angular cross-section breaks easily results, and records showing the number of "broken rails" are probably the most inaccurate of any of the types usually reported. But ascribing "broken rails" as generally due to seams eliminates entirely any consideration of *brittle metal,* that is, steel lacking in sufficient ductility. The very essence of good steel making requires a certain purification of the molten metal from various impurities, which, if present in finished rails to any great extent, would invite, without doubt, wholesale failures quite distinct in every way from those associated with moon-shaped breaks. Likewise, the heat treatment that the ingots and rails receive is recognized as among the most important matters of manufacture and have a decided bearing on the number of failures in service. In fact, good steel, whether it be from an open-hearth furnace or a converter, and its subsequent proper treatment in the soaking pits and rolling mill are fundamental necessities to insure against brittleness. And certainly the quality in steel called brittleness has no more relation to seams, per se, than has the question of how many ingots comprised the heat.

Under the heading of "Remedies," Mr. Wickhorst gives the minimum amounts of deoxidizers which should be added to molten steel in order that their full influence may be attained and a dead or quiet setting steel result. Thus, it might be inferred that simply by specifying the addition of these amounts of silicon or titanium or aluminum, wild steel would be avoided and the interior segregation of ingots greatly reduced, if not practically eliminated. Such is not the case at all. Different conditions of furnace charges and furnace working exert a tremendous influence on the character of the metal comprising the bath, so that different heats are widely different in their characteristics, and with the result that variable amounts of deoxidizers are necessary to produce the quiet setting steel desired in the molds. Raised or boiled top ingots are indicative of blow holes resulting in what can be termed physical unsoundness, and while considerable segregation is no doubt generally present in such cases, still it is questionable whether it is materially minimized by the use of so much deoxidizer as to make dead steel and flat top ingots. It would seem decidedly imprudent, therefore, in the light of present knowledge, to suggest the amount of deoxidizer that should be added, especially when other conditions, as for example, temperature, plays so prominent a part.

The adoption of a uniform top discard of 25 or 30 per cent. from the ingots, or making the ingots by a "hot top" process is suggested as the two courses open to reasonably insure against "harmful" segregation being present in rails. What is "harmful" segregation, or, in other words, how much segregation can be present without split heads, and their accompaniments, resulting? As far as known this important question has not been settled except in a general way by the Pennsylvania Railroad experiments made mostly, if not entirely, on failed rails. Whether "harmful" segregation is wholly that which occurs in masses, or whether finely divided and distributed increased amounts of carbon and phosphorus is the more detrimental in the long run can only be answered at present by speculation and guess-work.

The nick and break test on each ingot was designed for the express purpose of avoiding a uniform top discard of 25 to 30 per cent. in order to insure sound rails, and it is manifestly unjust now to ascribe that amount of uniform top discard as necessary. The admission of such necessity means that in almost ten years of work by the Rail Committee no particular progress has been made, either in testing rails or in otherwise obtaining results toward a cure of the source of greatest rail trouble. It is just ten years since the same question was discussed by the American Railway Association and by Mr. William Metcalf, than whom no greater steel metallurgist ever lived, suggested considering each ingot as a unit by itself, and, instead of making an extreme and uniform amount of top discard, in many instances of obviously good metal, of making a nick and break test on the top end of the top rail of each ingot for the purpose of proving or disproving its freedom from interior defects. Under such a method of testing the amount of top discard to insure sound rails is greatly reduced from the uniform 25 or 30 per cent. mentioned, and becomes entirely dependent upon the skill of the manufacturer. Over 50,000 tons of rail were rolled and tested at one mill in 1915 under the plan proposed by Mr. Metcalf, all with such eminent success in every detail that the practicability of the plan is well proven. The specifications for the nick and break test on each ingot and the results obtained with it have been thoroughly described in an

A. R. E. A. Bulletin, and if further recognition of the facts therein covered are lacking it would seem as if the matter should be more completely investigated rather than totally abandoned. It can only be regretted that after ten years' work on rails the value of the nick and break test is so lightly considered as to not deserve mention at all in Mr. Wickhorst's paper.

Author's Closure.—Mr. Gennet's comments are an amplification of my paper, rather than a criticism, and to a large extent I endorse his remarks. As regards the amount of deoxidizer used, the figures given in the original paper were based upon the results of extensive experiments reported to the Association at different times and show about the "order of magnitude" of the amount required of the several deoxidizers, which may, indeed, vary somewhat under different conditions.

The term "brittleness" is one that describes a condition or symptom rather than a cause; that is, after finding a condition of brittleness or lack of ductility, the cause is still to be looked for, before a remedy can be effected. Where a rail is brittle in the drop test or other bending test, an examination of the fracture shows that the initial point of the break is usually in the interior of the rail and not at the surface of the section where the fibers are stretched most. That is, brittleness is an interior condition of the rail, rather than a surface condition.

As regards top discard from the ingot, it is immaterial, as an abstract principle, whether any discard is made, so long as the proper qualities are produced in the rails, but it is also probably true that a large top discard is necessary from rail ingots as ordinarily made, to produce rails satisfactory for heavy service.

With Mr. Gennet, I look favorably on the nick and break test on every ingot and rather feel that the art of testing will proceed to the point where a full destruction test will be made of a sample representing each ingot, by the drop test, or preferably by some quicker method; for example, the hydraulic bender.

DISCUSSION OF IMPACT FORMULA.

The following correspondence between Professor E. E. Turneaure, Dean of the College of Engineering, University of Wisconsin, and Mr. Gustav Lindenthal, Consulting Engineer, New York City, is published herewith as being a matter of very great interest to Bridge Engineers and members of the Association generally:

March 27, 1917.

Mr. Gustav Lindenthal,
Consulting Engineer,
68 William Street, New York City.

Dear Sir:—

You have, perhaps, followed somewhat the work of the Iron and Steel Structures Committee of the American Railway Engineering Association on the subject of Impact, and noted the experiments which have been carried on by the Sub-Committee at intervals for a number of years. The results of these experiments, together with such experimental data as were otherwise available, have led to the formulation of an impact formula, as follows:

$$I = \frac{30{,}000}{30{,}000 + L^2}$$

It has seemed to the Committee that, from all the data we could obtain, this formula covers fairly well the maximum impact effect to be expected in ordinary railroad bridges.

In your review of Mr. Waddell's treatise on bridges, published in the Engineering News December 21, 1916, you refer to the experimental data mentioned by Mr. Waddell as being inconclusive, and call attention to the formula suggested by yourself in an article published in the Engineering News August 1, 1912. This formula was examined, among others, by the Sub-Committee on Impact, and it did not seem to them that it would be a satisfactory basis for the A. R. E. A. specifications. I have taken occasion to look over your article again, and, in view of your statement in your review of Mr. Waddell's work, would like to inquire if you can give me any further information as to the basis of your formula than is contained in the above-mentioned article.

You say something in that article about the formula being based on observations which you have made, and that, in your judgment, it is of quite general applicability. If the observation or data which you have in mind have been published, or are available, the Sub-Committee would be very glad, indeed, to have access to this information.

Of course, the proposed formula of the Committee is applicable only to structures carrying railroad trains headed by the ordinary steam locomotive, and undoubtedly should be modified for application to structures carrying electric trains only. The Sub-Committee made a number of experiments last summer on the Norfolk & Western Railway, where electric traction was used, and expects to make further experiments on the C. M. & St. P. road during the coming summer on its electrified section. There is no question that we will find much smaller impact under electric locomotives than under steam locomotives, and, with well-balanced machines, the impact effect should be very small, as we have already found.

The Committee does not, of course, claim that the experiments made by it are wholly conclusive, but the information obtained by these and other similar tests is the best evidence available on the subject, so far as we know. In the case of spans below 50 feet in length, bridge stringers and hangers so arranged that there is little elasticity between the rail and the member in question, the experiments are not very satisfactory, and no great accuracy is claimed for them, as is stated in our reports. On the other hand, in the case of girder flanges and main truss members in bridges exceeding about 50 feet in span length, I believe our results are, on the whole, satisfactory, and may be taken as a fair measure of live load effect. We have seen no evidence, in all of our numerous experiments, that the application of load produces anything like a shock or blow which cannot be measured by extensometers and deflectometers. We therefore feel that we have good reason to place reliance upon our results, and that an impact formula based upon the maximum values obtained in these experiments in which excessive speeds have been used may safely be taken to represent what is actually understood as impact. The Committee, however, desires to secure all possible information, and is very glad of all suggestions on this important subject, and would be pleased to receive any information from you in any way supplementing your published report.

Yours very truly,
(Signed) F. E. TURNEAURE,
Chairman, Sub-Committee on Impact.

April 17, 1917.

Professor F. E. Turneaure, Dean,
The University of Wisconsin,
Madison, Wisconsin.

Dear Sir:—

I have received your letter of March 27. Repeated absences from the city prevented me from replying earlier.

I beg leave to enclose a copy of my article on my impact formula, having on the last page an addendum not published.

When speaking of the effect of live load plus shock on steel as equivalent to three times the effect of quiescent load, I do not mean stress or strain. This I have expressly emphasized in my article published in Engineering News August 1, 1912. I thought I had made this distinction clear, to avoid misunderstanding. It would, perhaps, have been better if I had used the words "durability" or "resistance to deterioration" in place of effect or physical effect.

The principal object of adding a value for the effect of shock and vibration to the static stress from live load is to make all parts of the bridge equally durable. Guided by that thought, I take as the basis for my reasoning the observed facts mentioned in my article.

If I understand you correctly, you ask me whether I have myself observed the facts, and whether they have been published or are available? I am surprised at the question. The difference in factors of safety for dead load and for shock is so generally known as to require no discussion (see Kent's Pocket Book, p. 353, or Mechanical Engineers' Handbook, p. 390, and others).

As regards rails, it is my opinion that the factor of safety should be much higher than 9. It should be as high as in locomotive axles, where it runs between 15 and 20. The highest fiber stress in the 130-lb. rail of the Pennsylvania Railroad under a driver-wheel load of 35,000 lbs. (quiescent and considered as a simple beam on two supports) is not over 10,000. Two kinds of steel have been tried—a high carbon with 90,000 to 100,000 and a lower carbon with 75,000 to 85,000. The fractures in the low carbon are several times as numerous as in the high carbon steel under the same wheel loads and same heavy traffic. Fractures would probably not occur at all with the same quality of steel, if that rail were made, say, a 200-lb. section with a fiber stress of 5,000 (quiescent).

If the rails on a steel bridge were, for instance, clamped and fastened directly to the top of stringers (an obsolete construction, long out of use, which I observed in Switzerland 45 years ago, and which gave constant trouble with rivets getting loose throughout the bridge frame), then the initial factor of safety for shock on such a construction would have to be much higher than 9, in my method of deduction.

But inasmuch as the wooden ties greatly diminish and cushion the force of the blows delivered upon the rails vertically and horizontally, I consider that a factor of safety of 9 for shock of both kinds in the steel immediately below the tie is amply safe enough to start with in my deductions.

You seem to have great confidence in measurements with extensometers and deflectors on bridges under passing loads. I do not share it, for the reasons stated on page 2 of my enclosed article. The sharp, vicious *side* blows and shocks on the rails and bridge frame are not thus recordable at all. Of course, you will get some vertical values, varying up and down with length of span from which, when plotted, some rule or curve may be formulated. If such curve should happen to coincide with the values deduced from my formula for same conditions, it would be a proof of correctness of the Empirical formula. At present, I believe that authentic experience with the durability of steel under shock and vibration is the safest guidance in the deduction of a rule for properly proportioning steel members.

If an axle, piston-rod, rail or other member subject to shock breaks, make it stronger, until it stops breaking. Finally the size or cross-section is obtained which will not break, and from it the proper factor of safety relative to static stress for that member can then be deduced. These things cannot be determined *a priori* from theory, but are entirely a matter of tests and experience.

In that connection the experience of Metcalf is instructive in the well-known case, when he replaced the piston-rod of a steam hammer of soft steel with one of hard steel just to hand. He ascribed the longer duration of the hard steel rod (of same cross-section) to its greater resistance to vibration, by reason of its greater hardness, when in fact it was due, as I pointed out at the time, simply to its greater strength, that is, to the greater factor of safety. The steel being stronger than the previous soft steel for the same work, lasted longer (see Metallurgy of Steel, by Prof. H. M. Howe, p. 199, and footnote).

This view is confirmed by the further experiments of Metcalf (see English work on Steel by J. S. Jeans, p. 656) with steel rods subjected in a special machine to 1,200 alterations of stress per minute (axial tension and compression). Each such stress may be considered as a shock lasting 1/40 second, too short a time for measuring its intensity by any instrument. It may be assumed, however, that, considered as a static stress, its value was far within the elastic limit. Yet because the time was too short for the molecules to react elastically to the stresses, some of the rods before they broke got red hot in the middle, where the stresses met. But it will be noticed that the rods which were twice as strong lasted four times as long. That is, rods having double the factor of safety resisted deterioration four times longer. This, it seems to me, is the important and significant fact for the Engineer to consider when estimating the cross-sections for durability in a structure exposed to shock, and that is the reason why I prefer to base my deductions for an impact formula upon factors of safety derived from experience rather than upon uncertain or deceptive extensometer or deflectometer measurements.

My impact formula is as speedy and simple to use as any of the Empiric formulæ. Daily experience in my office proves this.

I enclose a blue-print showing the curves of weights of steel in plate girders from 10-ft. to 125-ft. span. You will notice that my formula requires more steel until the 125-ft. span is reached. This is as it should be; plate-girder bridges sustain large horizontal shocks, usually neglected. They give out mostly through rivets getting loose, which is an evil impossible of correction when started. Plate girders should always be of stout construction and have strong details, which in all bridge frames should prevailingly be influenced by the impact stresses.

My formula required also more steel for truss bridges up to 300-ft. span. Beyond that limit my formula shows a saving of steel in the trusses, the saving increasing with length of span. That, also, is as it should be. As an accompanying advantage, secondary stresses are smaller with lighter truss members, retaining, however, details, splices and connections stronger, proportionately, than the connected members. A bridge thus dimensioned can give out only in the members and not in the details or connections, which is also as it should be.

My formula can be used economically with same basic unit for the longest practicable spans, as well as for short spans. The Empirical formula, with 16,000 lbs. basic stress, gives for long spans trusses disproportionately heavy, as compared with floor system. If an extra strong bridge is wanted, it is more rational to assume a big live load with a high stress than a low unit stress along with a smaller live load.

My formula gives larger impact values for higher steels, and lower values for cast-iron, wooden and masonry bridges, and it automatically makes allowance for heavy stone-ballasted floors, such as are coming to be more generally used. The Empirical formula makes no such allowances. A different formula would have to be gotten up for each of these classes of bridges.

A deduced formula can be readily modified for any given load conditions, because the elements for which it is deduced are known. If the locomotives get longer, or electric traction replaces steam traction, or highway traffic is combined with railroad traffic, for each case a suitable impact formula can be deduced, while Empirical formulæ for such cases would have to be devised on new guesses. The deduced formula is also readily adapted to the metric system. My formula proved itself to be a great convenience, and very simple, in all bridge computations in my office, and especially so in comparisons as to economy of one bridge system to another in different materials, all on the same basic conditions. That cannot be done satisfactorily with Empirical formulæ.

Your formula will give lighter trusses for the longer spans than the Schneider formula, but for my work, I find my formula preferable for the reasons stated. Yours truly,

(Signed) G. Lindenthal.

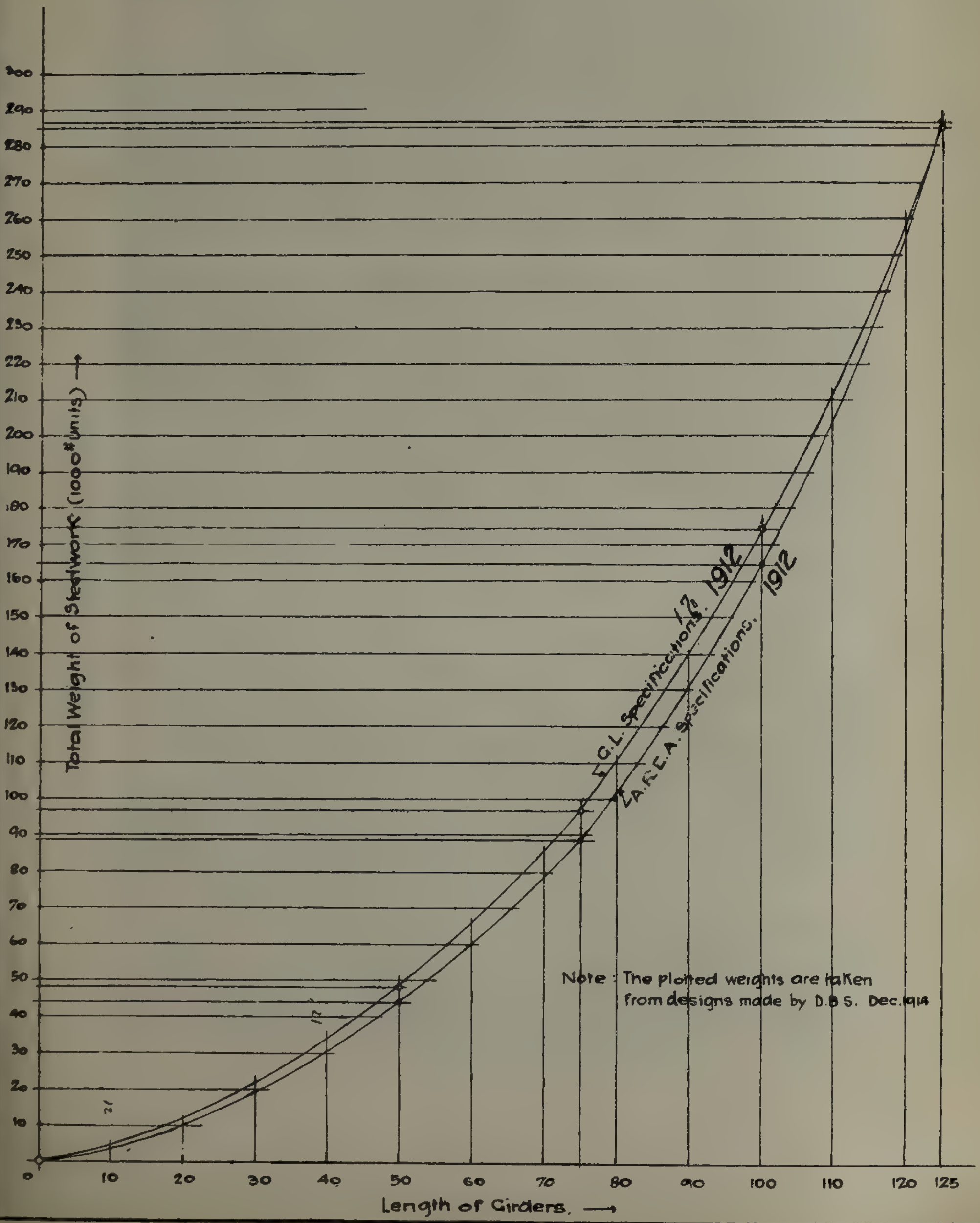
Madison, Wis., May 4, 1917.

Mr. Gustav Lindenthal,
Consulting Engineer,
68 William Street, New York City.

Dear Sir:—

Your letter of April 17 received, and contents read with much interest. I thank you very much for your comments and criticisms. I did not intend to intimate that no experiments or experience had been had with

Weight of Steelwork (excl. bearings)
of
Plate Girder Spans (single Tr.)
(Open Track - 700# p.l.ft.
Live load E.60)
Comparison { G.L. Specifications, June 1912
A.R.E A. Specifications. 1912



Note: The plotted weights are taken from designs made by D.B.S. Dec. 1914 respect to such conditions of load as you mention on the first page of your letter. I fully appreciate that for machinery, car axles, and the like, subjected not only to shock, but to rapidly reversing stresses, a high factor of safety is required, and I would not pretend to dispute what you say on this point. When it comes to main truss members of bridge spans and flanges of long plate girders, I think the case is entirely different. I do not think that the two conditions are at all comparable, and that it is impracticable to draw satisfactory conclusions relative to such bridge members from the tests on shock to which you refer. My inquiry concerning tests and observations had reference to the case of the bridge structure, rather than to the other.

I believe that the live-load stresses in bridge members, such as above indicated, are not only very much less than in the members subjected to blows and shocks, such as you mention, but have entirely different "quality." I do not believe the word "shock" is really a properly descriptive word for main truss members of bridges of considerable span length. The behavior of such members is entirely different from such members as rails and stringers placed closely under the rail, and such variation of stress as they are subjected to are relatively slow. They act more like slowly moving springs in which stresses can be readily measured.

In all of our work I have observed nothing in the way of a blow or shock occurring on the main truss members and flanges of long girders. When the structure is vibrating, the stresses in these members do, of course, vary, but this variation is relatively slow—not more than three or four vibrations per second, and wholly different in effect from the rapidly alternating stresses in the tests mentioned in your letter. I think all members of the Committee who have carefully observed the tests in the field would concur in this opinion.

You mention the question of side blows and shocks. These, of course, do occur, but as a "blow" or "shock," the effect is hardly carried into the main truss members. The chord members feel the effect of these side blows only as the entire truss is deflected laterally. These deflections have been measured, and stresses produced thereby are indicated by extensometers in exactly the same manner as stresses due to vertical loads. As a matter of fact, lateral vibrations of the structure are generally less rapid than vertical vibrations, as the structure is more flexible in a lateral direction.

Coming to the question of actual figures, I understand that your formula starts with an impact of practically 200 per cent. for very short spans (speaking in terms of percentage of static live-load stress). Assuming two locomotives heading a train of Cooper's class, E-60, the impact percentages from your formula would figure out approximately 160 per cent. for 100-ft. span, 115 per cent. for 200-ft. span, and about 60 per cent. for 300-ft. span. Considering a 100-ft. span plate girder, I am entirely convinced that 160 per cent. of the static live-load stress is very much greater than would represent the actual facts. Assuming, for the sake of argument that 200 per cent. impact is correct for a very short span stringer, for example, it seems to me, from all observations I have been able to make, that the difference in behavior of the very short span and the 100-ft. span is very much greater than is represented by the difference between 200 per cent. and 160 per cent. The flanges of a 100-ft. span plate girder, particularly in case of a through girder, with ballast floor, cannot possibly be subjected to any great shock. The entire structure will be set into vibration, if a synchronous effect is produced by locomotive drivers, and this synchronous effect will not differ greatly whether the ballast is present or not. The relatively slow vibrations set up by this synchcronous effect can hardly be described as "shock." They produce stresses which are very easily measured. It has been our experience that the effect of ballast floors is very considerable on stringers and floor beams, and shows up very decidedly in the character of vibrations produced. The shock and jarring present in the ordinary stringer, especially if placed directly under the rail, is almost wholly absent and the resulting curves are about as smooth and steady as in main truss members. The effect of ballast is, however, not great on main truss members, as these are quite free from shock excepting as this term might be used to indicate the vibration of the entire structure. Ballast floors do not prevent such vibration.

In this connection, I note that you state that your formula readily takes account of the influence of ballast floors. The only way in which this is done is by the indirect effect of increased dead weight. Such effect in your formula would be practically nil for stringers and floor beams, but would amount to something in the case of truss members. If any allowance is to be made for ballast floors, I think it should be made in such members as stringers and floor beams, rather than in main truss members.

I fully agree with you that future increase in load should not be provided for by using low unit stresses, but by assuming a live load which, it is expected, may, at some future time, be in use. Neither do I think that such extra strength should be provided for in the impact formula.

As stated in my previous letter, the Committee does not claim any great accuracy in its tests for spans of 25 feet or less. For such spans, it has been willing to accept established practice of approximately 100 per cent. impact. Considering the overload to which many railroad structures have been subjected before details have begun to fail, it would appear that 100 per cent. for stringers and similar members, with the usual wooden floor system, has been satisfactory. Failures in such structures have usually occurred in end details where heavy secondary stresses have existed without being fully recognized and provided for.

However, the Sub-Committee has been principally concerned with the subject of impact percentages for girders and main members of trusses for spans of 50 feet upwards, and believes that its tests and observations are valuable and significant with respect to such structures.

Yours very truly,

(Signed) F. E. Turneaure.

May 14, 1917.

Prof. F. E. Turneaure,
Dean, University of Wisconsin,
Madison, Wis.

Dear Sir:

I have received your letter of May 4th. My reference in my last letter to certain tests was intended to indicate that deterioration of steel when subjected to dynamic stresses is postponed if not prevented by a large enough factor of safety, which must be derived from experience.

You believe that the dynamic stresses in main truss members and flanges of long girders cannot be compared with those in axles, etc. I don't see why. The stresses are of course not of the same intensity but they are of similar nature and effect.

An incident which I once witnessed may illustrate my meaning: A 4-inch rusty screw plug in a hydrant was so tight that it could not be loosened by a wrench with a lever 3 ft. long. A pull by two men with block and tackle fastened to the end of the iron lever had only the effect of bending it. One of the men was left to pull the rope with all his strength while the other man repeatedly tapped the lever with a

3-lb. hammer about 6 inches from the fulcrum. After about ten sharp strokes the lever commenced to move, very slowly at first and finally the screw plug was loosened. The same result would be obtained if the man had used a heavy wooden mallet; or if he had used a wooden block between hammer and the bar, striking the block with the hammer (the wooden tie between rail and girder). The only difference would be that it would require several times as many blows in that way.

What I want to point out is that we have here the recordable slow statical fiber stress from the pull on the lever, combined with the shock from the hammer, the fiber stress of which may also be recorded to some extent. But will it record the actual stress (static plus shock) in the lever? I doubt it. Will that recorded stress be less or more than the slow statical stress produced by two men pulling the tackle hard enough to bend the lever? It will probably be much less and yet its repetition produces a result different from that of bending the lever. That result is molecular disintegration at the weakest spot, which is in this case the corroded screw thread.

The weak spots in bridges are most liable to occur at the connections where the stresses are first concentrated, then divided up among the members. The shock will find the weak places and do its work there, or it may travel on, getting weaker on the trip by reason of the continuous elastic resistance of the metal before reaching the resting place on the abutment. You claim these stresses and accompanying vibrations are of a different quality from shock. Yet shock is their father. Without shock they would not occur. Vibration is only a manifestation of shock after it has done its work of deterioration. Of course the time element of the spring, which you mention, comes into play to lessen the effect on long distance members. Without shock a highly stressed girder under a quiescent load including its own will never develop loose rivets although they may be overstressed. But in such girders loose rivets will occur under much smaller loads when accompanied by shock. All this is matter of common knowledge.

What is shock anyway? We may say that it is an instantaneous force acting upon matter. But theoretically it can be instantaneous only when the matter acted upon is inelastic. As such material does not exist, all material being elastic, any force must act longer than an instant. We recognize its effect as energy doing work and not as stress. The deduction of dynamic stress by the kinetic theory is thus not verifiable and of no practical value.

The experiments of Wohler, Baushinger, Benjamin Baker and others were not with dynamic stresses but with rapid repetitions of static stresses kept strictly within predetermined limits, sometimes the repetitions being so rapid, as in the Metcalf tests, as to exceed the velocity of stress transference in steel.

If static stresses kept within prescribed limits can deteriorate iron depending upon their range, number and rapidity of repetitions, dynamic stresses, whose range is not recordable but whose intensity very likely greatly and frequently exceeds the recordable static stresses, will do so. The only safe conclusion that we can draw is that the larger the cross-section the smaller the deterioration will be. As to any rule for it we must depend upon experience.

The physicist has no more accurate data upon molecular deterioration, theoretical or experimental, than those already known. The Engineer steps in and from his experience devises a rule that will cover the case in bridges until something more definite may be found. You have one rule; Waddell has another; Seaman and others have theirs. So have also Prof. Melan and others abroad. I have corresponded on this matter with Professor Mehrtens, who died a few months ago, and with Professor Melan, who published an article upon my rule, but which I did not receive because of the war. Dr. Zimmerman discussed with me his investigations 20 years ago, before they were published. I always considered his deductions as giving values too small for the rough work on railroads, particularly when whole trains are made up of dead locomotives in times of war emergencies.

With your impact formula the unit stresses for dead and live load without impact vary from 9000 in short stringers to 15,500 in truss members of long spans. With my impact formula the corresponding figures are 7000 and 19,500. I consider 20,000 all sufficient for dead load and for the basic unit stress, against your 16,000 which appears to me wasteful. In my short spans the violent stresses meet more metal than in yours to resist them. In spans of about 200 ft. the cross-sections with your formula and with mine will not vary much. In my long span trusses the live load stresses meet sufficient metal to make them equally durable with the steel in the floor.

As regards ballast floors, which weigh about 1000 lbs. more per lin. ft. than the open tie floor, my formula shows a decided comparative saving in steel, other things being equal.

It will not be long before stone ballasted floors on bridges will cost less than the open tie floor, with wooden ties of the necessary large section getting more expensive all the time. In that case my impact formula shows the decided saving of metal in truss members which is justified by reason of smaller impact stresses from such floors.

It is interesting to compare strain sheets based upon my impact formula with other strain sheets for the same designs and to observe where the differences occur.

I have examined in the course of time many iron bridges. I have found very few that failed in truss members between connections. But many that were unsafe by reason of bad and overstrained details; floors always giving out first. They get the knocks and maximum stresses every time a locomotive passes, whereas the trusses may not get the maximum stresses and the greatly reduced shocks more than a few times a year. Therefore I consider the range in unit stress from 7000 to 19,500 as better adapted for insuring equal durability in all parts than your corresponding range of unit stress from 9000 to 15,500.

I prefer my deduced rule as being rational, simple, and giving results entirely justified by observations, safe and truly economical. I consider the top-heavy, violently swaying tender upon badly mated wheels at fast speeds as bad for the bridge as the locomotive with counterweighted drivers; 200 per cent. for bad behavior for their whole length is not too much. Great speed on a poor bridge track plays havoc with impact formulae. Locomotives are getting longer and heavier. Some of them already over 100 ft. long with 18 driving axles (as on the Virginian R. R.). I advise my clients to build their bridges strong and heavy enough. Some of them are replacing already the fourth generation of girders. When it comes to long spans, with two and more tracks, or to important highway bridges of very long spans, much money can be wasted by bad design and poor judgment, so that an inferior bridge may cost very much more than a good strong bridge. But this is almost commonplace to Bridge Engineers.

Yours very truly,

(Signed) G. Lindenthal.

IMPACT FORMULA.

By G. Lindenthal.

(Synopsis from the article in Engineering News, August 1, 1912.)

The causes which produce dynamic stresses on railroad bridges, although long known, are too complex, numerous and variable for accurate determination.

Anyone that ever rode on a locomotive is aware that the concussions and vibrations of the machine at high speeds are exceedingly violent. Driving-wheels can be balanced but for one speed, usually a medium speed. The wheel pressures from a locomotive standing still have no resemblance to the wheel pressures at high speed; these latter may vary from minus 50 per cent. at one end to plus 200 per cent. simultaneously at the other end of the driving axle.

The tremors of the locomotive are transmitted to the track, which receives vertical blows as well as lateral ones. Poor rail joints further increase the swaying motion of the ponderous machine, which at the high speed of our limited expresses is thus leaping rather than smoothly rolling. The tender immediately connected with the locomotive receives from it a share of the concussions and of the lateral motion, called nosing. On long bridges the effect of the shocks from locomotive and tender is supplemented by the shocks of the cars from flat wheels, axles out of square, etc.

The strains from all these causes defy analysis. In a general way we know that on short spans and light bridges the dynamic effects are large, and that in long spans or on heavy bridges they are much smaller.

All rules in use for impact are empirical. Some of them give, for the usual structural steel, the usual open floor, and for ordinary spans (up to 200 ft.), values fairly in agrement with observed effects; but they do not fit other conditions. Some other rules, which pretend to a scientific basis, have less merit. Such, for instance, is the rule of doubling the live load stress (i. e., adding 100 per cent. in all cases), or what is the same thing, making the unit stress for live load equal to half the unit stress for dead load, on the theory that a load suddenly applied will cause momentarily double the static stress of the same load gradually applied (within the elastic limit). This law is true only when the sudden loading is applied without shock or concussion—an essential condition which, however, does not occur outside of a laboratory. All railroad loads are accompanied by more or less shock, concussions and vibrations even at slow speeds. Static stress may be relatively small and accompanying shock large, or the reverse. In any event, if the known stress plus (unknown) shock, strain the metal below its elastic limit, it will be safe; if beyond the elastic limit, then the metal will break from frequent repetitions in course of time.

It can be assumed that the intensity of these shocks increases as the square of the speed of the trains.

To harmonize the misapplied theory of sudden load with observed facts, it was found necessary to use different unit-stresses for different members in the same bridge—one for the stringers, another for the floor beams, another for web members, another for chords, etc. Sometimes 6 to 10 different axial unit-stresses (for tension, reduced for compression) are thus used in the same design. This variety requires a corresponding variety in the unit-stresses for shear, bearing, bending, etc., resulting in very cumbersome, confusing and rather imaginary strain sheets.

Other impact formulas use a single basic unit-stress and assume a live-load addition varying in some inverse ratio with loaded length of span, from an upper limiting value of 80 to 125 per cent. addition.

Attempts have also been made to deduce formulas from measurement of strains in existing bridges, but with puzzling results. Primary and secondary strains from live loads are often of opposite sign and cannot very well be separated in such measurements; besides, it is a mooted question whether the momentary strains from shock can be accurately measured at all with any instrument so far invented.

For one reason or other the various formulas in use appeared unsuitable for the variety of structures to be designed. A new formula was therefore evolved by the writer, which gives for all cases values as close to truth, it is believed, as can be obtained with elements so undefinable.

DERIVATION OF NEW IMPACT FORMULA.

The reasoning is based upon the factor of safety required to meet shock and starts from the well-known fact that good iron and steel (when the dead-load stresses in them are so small as to be negligible) will safely and permanently endure the stresses from external forces accompanied by the usual shocks, concussions and vibrations of moving masses, when dimensioned with a factor of safety of 9 to 10 for the statical stress. If designed with a much smaller margin of safety such parts break sooner or later. Experience has determined that fact with shafts, car and locomotive axles, connecting rods, gear wheels, machinery parts of all kinds, rails, etc., all exposed to shock.

We have also the other fact that for quiescent stresses, as from dead-load, a unit-stress of one-third of the ultimate strength (factor of safety of 3) or two-thirds of the elastic limit of the steel, is absolutely safe.

(The terms "stress," i. e., the force exerted in a body, and "strain," i. e., the change of form under stress, are in this article used interchangeably. The distinctions made by physicists may not always be observed by engineers.)

For members subjected to stresses from both dead-load and live-load, the safe unit-stress will therefore be somewhere between one-third and one-ninth of the ultimate strength. As it is desired to use *one-third of the ultimate as the basic stress throughout,* it follows that the addition for the dynamic increment (I in the formula for total stress, $S=D+L+I$) will vary from 200 per cent. for members having only live-load stress, to zero for members having no live-load stress.

For any case in which dead and live-load stresses occur together the increment will depend upon and be modified by two principal conditions.

First Condition.

The intensity of the impact depends upon the masses (or weights) of the locomotives (including tenders) and the cars.

The real troublemakers for tracks and bridges are (as stated before) the locomotives; the top-heavy swaying tenders are only little less injurious. For the locomotives and tenders an addition of average 200 per cent. to the static stress will bring the strains from them within the indicated factor of safety of 9. This is the same thing as taking three times the quiescent statical load.

The shock from the cars is less. They roll comparatively smoothly behind the locomotives, except for occasional flat wheels and poor rail-joins. To account for the latter an addition of 100 per cent. is ample. But with rails 33 ft. long, and with the heaviest cars having four axles in about the same length, only every fourth axle may be assumed as delivering simultaneously that 100 per cent. impact at the rail joints. Therefore 25 per cent. of the car-loading per linear foot may be taken as an ample provision for impact from cars.

If Q is the weight of locomotives and tenders, q the weight of the car-loading per linear unit of track, and a the length of train behind the tender, then the intensity of impact may be expressed as a stress P.

$$P = L \frac{200\% \, Q + 25\% \, q a}{Q + qa} = L \frac{8 Q + q a}{4 Q + 4 q a} \qquad (1)$$

Second Condition.

The effect of the impact as distinguished from its intensity, is also a factor. The intensity may be said to exist at the beginning of the shock, the effect at the end of it.

Opposed to the shock (accompanying the statical stress from live-load) is the elastic resistance of the entire cross-section of the member, which is always proportioned at least for both dead and live-load $(4 + L)$. The elastic resistance has a retarding or braking effect upon shock. Its momentum is converted into the work of momentary elastic changes in the form or length of the members, manifesting itself by vibration. Although the forces act in an immeasurably short time and through an insensibly short distance, and cannot be accurately known, it is obvious that the elastic resistance to shock increases with the mass or in this case with the cross-section impinged upon, and that it decreases the intensity of the shock provided the strains are within the elastic limit of the material. It is impossible to equate dynamic work, were it known as to amount, with statical forces (as the energy of shock opposed by elastic retardation) in terms of stress, which alone could be used for dimensioning. But approximately we can say that the reduction of the impact will be proportional to the cross-section of the member and can be expressed by the relation,

$$\frac{L}{D + L} \qquad (2)$$

in which L represents the live-load stress plus any effect of sudden loading and shock, and $D + L$ represents the cross-section of the member. This term is already in use in impact formulas.

CONCURRENT LIVE-LOAD EFFECTS.

It should be kept in view that strain from moving load or live-load does not resemble the quiescent strain from dead-load. Live-load strain is restless, oscillating up and down from its static value. During each oscillation it is subject to acceleration by gravity, reaches a maximum, and is then decreasing through retardation from the elastic resistance of the material; and so on until the oscillations die out.

The effect of shock is different. When its intensity is largest (in the beginning), the strain from it is zero; but as soon as its intensity produces strain, it instantly decreases in intensity.

These two strain effects, one alternately growing and decreasing through oscillation and retardation, the other instantaneous but reduced by retardation—are concurrent and inseparably comingled, which makes it further impossible to ever determine with any accuracy their relative strain values.

The value P of equation (1) can from experience be safely assumed to cover within the limits of $P=2L$ both effects, just as the retarding force acting upon P can be assumed to be approximately proportional to

$$\frac{L}{D+L}$$

The cushioning effect of stone ballast or other heavy floor, for instance, is thus allowed for in that the dead-load stress D will then be larger, and thus the retarding force greater, and the impact smaller.

Combining the two relations (1) and (2) we obtain the true increment

$$I = \frac{L}{L+D} \times P = \frac{L}{L+D} \times L \frac{8Q + qa}{4Q+4qa}$$

$$= \frac{L^2}{L+D} \times \frac{8Q + qa}{4Q+4qa} \qquad (3)$$

which is the general form for railroad bridges, capable of use with either English or metric measures.

Substituting for Q the weight of two locomotives and tenders (of Cooper's E-60 loading) $= 2 \times 426{,}000 = 952{,}000$, and for q its corresponding value of 6000 lbs. we obtain

$$I = \frac{8 \times 952{,}000 + a\,6000}{4 \times 952{,}000 + a \times 4 \times 6000} \quad \frac{L^2}{L+D}$$

or approximately,

$$I = \frac{L^2}{D+L} \times \frac{1200 + a}{600 + 4a} \qquad (4)$$

which is the formula used among others for the bridges of the New York Connecting R. R. and for the Sciotoville bridge over the Ohio River.

The values obtained from the formulas (3) and (4) give the increment for impact in percentages of the static live-load stress L, and are sufficiently close for all practical purposes.

No one knows, and probably no one can know, whether the live-load stress plus shock occurring under conditions named is some multiple of the static quiescent stress. We need not care much whether it is or not, because the important and guiding fact is not that of stress but its physical effect upon steel deduced from experience as regards its durability and safety.

In other words, the impact formula gives the factor of safety, or margin as it were, in terms of the static stress from dead and live-load for each bridge member, as above shown, to the end that all bridge members, including the least frequently and the most frequently stressed, shall have equal durability.

ADAPTABILITY OF NEW IMPACT FORMULA.

In the impact formula

$$\frac{L^2}{D+L} \times \frac{8Q + aq}{4Q+4aq}$$

the values Q and q can be modified, if necessary, to suit the conditions of a special case. Safe and close-enough values can always be obtained, using round figures and good judgment.

The weight of locomotives (and their number) may be varied as needed.

For smooth-rolling electrical cars, in which the rotating parts require no counterweight, the value Q disappears altogether and the impact becomes small, as it should.

For 60-ft. rails the value q can be taken smaller than 25 per cent.

For ballasted floor the impact will be less than for open floor, etc.

The formula can be readily adjusted, as needed, to road bridges with their usual concentrated loads. It is also adaptable to bridges of concrete and wood.

On railroads with more than one track it is assumed as possible that the impact effect from locomotives on different tracks is a multiple of the number of tracks, because the impact results mainly from the unbalanced driving wheels at high speed, although the probability of high speed on all tracks and of a maximum combined impact is smaller as the number of tracks increases.

On the other hand, there is no probability that the combined impact from cars on different tracks is a multiple of one track, because that would require that the blows caused mainly by flat wheels and poor rail joints would happen simultaneously on all tracks and at all joints, which is not at all likely.

Therefore, taking the impact at 200 per cent. of the locomotives and tenders on all tracks and at 25 per cent. of the cars whether one or more tracks and denoting the number of tracks with n, the second quotient of the impact formula can be expressed as follows:

$$\frac{200\%\,Qn + 25\%\,qa}{Qn \quad + \quad qan} = \frac{8Q + \frac{qa}{n}}{4Q + 4qa}$$

or for Cooper's E-60 loading, approximately $\dfrac{1200 + \frac{a}{n}}{600 + 4a}$

The Impact Formula for railroad bridges thus becomes:

$$I = \frac{L^2}{D + L} \quad \frac{1200 + \frac{a}{n}}{600 + 4a}.$$

This formula gives reasonable results for all span lengths and different numbers of tracks.

ADDENDUM.

COMPARISON OF RESULTS WITH TWO IMPACT FORMULAS.

The basic unit stress of 20,000 in the Lindenthal Specifications and formula is (as already mentioned) ⅔ of the minimum elastic limit or ⅓ of the minimum ultimate strength of structural steel. If a higher steel be used the unit stress would be correspondingly higher.

That basic stress (20,000) is amply safe for dead load and more rational than the 16,000 used for the same steel in the specifications and formula of the A. R. E. Ass'n, because in long spans where the dead load is larger than the live load, the amount of metal required to carry the dead load becomes unnecessarily large.

For ordinary truss spans the weight of steel with the Lindenthal specifications is about the same as with the American Railway Engineering Association specifications.

The following results taken from strain sheets will illustrate the working of the two formulas:

270 FT. SPAN.

4 track R. R. bridge, 2 riveted trusses, 50 ft. on centers, 50 ft. high, 12 panels 22 ft. 6 in. each, Cooper's E-60 loading,

	G. L. Formula.	*Old A. R. E. A. (Schneider's) Formula.*
Weight per lin. ft. of bridge—		
Stringers	2,100	2,100
Floorbeams	4,000	3.880
Trusses	9,180	9,372
Bracing	1,020	1,028
Steel, lin. ft.	16,300	16,380
Track	2,800	2,800
Total d. l.	19,100	19,180
Total steel	4,401,000	4,422,600

2 SPANS 775 FT. EACH.

2 tracks, 2 continuous riveted trusses 38 ft. 9 in. on centers, 20 panels 38 ft. 9 in. each, Cooper's E-60 loading.

Trusses and Bracing	23,500,000	31,800,000
Stringers and Floorbeams	3,600,000	3,600,000
	27,100,000	35,400,000
Per lin. ft. bridge—		
Steel	17,500	22,800
Track	1,400	1,400
Total d. l. per l. ft.	18,900	24,200

The difference in steel weights with the old A. R. E. A. (Schneider's) formula and the new A. R. E. A. (Turneaure) formula is not large. The above strain sheets were made before the new formula was known. It would not materially affect the above comparison, which shows that while in the 270 ft. span the steel weights are practically the same, in the 775 ft. span the steel with the Lindenthal formula is 30 per cent. less than with the A. R. E. A. formula.

From which the conclusion appears justified that the A. R. E. A. formula is not suited for long spans, while the Lindenthal formula is suited alike for short and very long spans.

American Railway Engineering Association

VOL. 19, NO. 199 . . . . SEPTEMBER, 1917

NAVY DEPARTMENT.

CIRCULAR FOR THE INFORMATION OF PERSONS DESIRING TO ENTER THE CIVIL ENGINEER CORPS OF THE UNITED STATES NAVY.

1. Examination and Vacancies.

An examination will be held at the Navy Department, Washington, D. C., to fill existing vacancies and vacancies which may occur during the present calendar year, in the grade of assistant civil engineer, Corps of Civil Engineers, United States Navy.

The vacancies to be filled will number not less than ten. They will be filled by the appointment of candidates successfully passing the examinations. Appointees are commissioned with the rank of lieutenant (junior grade).

The examination to determine the candidate's professional fitness will comprise—

First.—A preliminary examination to determine the candidate's general fitness, based on his collegiate record, testimonials, statements of references, and professional experience. Candidates will not be assembled for this examination, but will submit their papers by mail to the Bureau of Yards and Docks, Navy Department, Examining Board, Washington, D. C.

Second.—A final examination, including an oral and written examination, to be held in Washington, D. C., and open only to those who have passed the preliminary examination.

2. Prerequisites for Eligibility.

A candidate who has passed his twenty-sixth birthday on July 1, 1917, will not be eligible for examination. The candidate must be an American citizen; must have received a degree from a college or university of recognized standing, showing that he has satisfactorily completed a course in civil, electrical, or mechanical engineering; must have had not less than 14 months' practical professional experience since graduation; and must be of good moral character and repute. The fact that a man is married will not militate against his eligibility.

Candidates who did not qualify in the preliminary examination in May, 1917, or who failed on the final examination in June, 1917, are not eligible for this examination. Candidates who qualified in the preliminary examination but did not complete the final examination are eligible.

3. Physical Examination.

Candidates before the final examination will be examined as to physical fitness by a board of medical examiners composed of two or more medical officers of the United States Navy. If found to be physically unfit, the candidate will not be further examined.

Candidates who are considering taking the coming examination should have the question of their physical soundness definitely determined by a physician before subjecting themselves to the time and expense incident to appearing before the examining board.

4. Physical Qualifications.

The physical qualifications of applicants for appointment as assistant civil engineers in the Navy are decided upon by an examining board consisting of medical officers of the Navy. The physical examination of candidates will precede the final professional examination. No one found physically disqualified will be examined further. No material physical defect will be waived in any case for any reason.

A candidate must declare under oath that he labors under no mental or constitutional disease or weakness, nor any other imperfection or disability which may interfere with the most efficient discharge of the duties of an officer in any climate.

No candidate over 26 years of age on July 1, 1917, will be eligible for examination.

Applicants will be required to satisfy the examining board regarding age. The height must be not less than 5 feet 6 inches, stripped.

PHYSICAL PROPORTIONS FOR HEIGHT, WEIGHT, AND CHEST MEASUREMENT.

Height. Inches.	Weight. Pounds.	Chest.* Inches.	Height. Inches.	Weight. Pounds.	Chest.* Inches.
66	132	33½	70	155	35½
67	134	34	71	162	36
68	141	34½	72	169	36¼
69	148	34¾	73	176	36¾

*Mean circumference.

It is not necessary that the applicant should conform exactly to the figures in the foregoing table, which is given to show what is regarded as a fair standard of physical proportions. A variation not exceeding 15 pounds, not to fall below 132 pounds in weight or 1 inch in the mean chest measurement, below the standard given in the table, is admissible when the candidate for appointment is active, has firm muscles, and is evidently vigorous and healthy. A chest expansion of less than 2½ inches is a sufficient cause for the rejection of the applicant.

Any one of the following conditions will be sufficient to cause rejection:

(*a*) Feeble constitution, poor physique, impaired general health.

(*b*) Any disease or deformtiy, either congenital or acquired, which would impair efficiency, such as weak or deranged intellect, cutaneous diseases, parasites of the skin or its appendages, deformity of the skull, abnormal curvature of the spine, torticollis, inefficiency of joints or limbs, deformity of joints or bones, either congenital or the result of disease or injury, epilepsy, or other convulsions, diseases of the eye, defective vision, color blindness, impaired hearing or disease of the ear, chronic nasal catarrh, ozena, polypi, great enlargement of the tonsils, impediment of speech, disease of heart or lungs, enlarged abdominal organs, evidence of sclerosis, tumors, hernia, undescended testicle, large varicocele, sarcocele, hydrocele, stricture, fistula, hemorrhoids, varicose veins, disease of the genito-urinary organs, deformed or diseased feet, evidences of intemperance or the morbid use of drugs, loss of many teeth or teeth generally unsound (teeth properly filled not to be considered unsound). Every applicant must have at least 20 sound teeth, and of these not less than 4 opposed incisors and 4 opposed molars.

(*c*) Any acute disease.

Acuteness of vision must be not less than 12/20 for each eye, unaided by glasses, and capable of correction by glasses to 20/20.

5. Date of Examinations.

All papers and other information required of candidates for the *preliminary examination* must reach the Bureau of Yards and Docks, Navy Department, Examining Board, Washington, D. C., by noon of October 31, 1917.

The date of the *final examination* will be announced after the rating of the papers in the preliminary examination has been completed, and while the exact date can not be given at this time it will in all probability be held about one month thereafter.

6. Preliminary Examination.

A permit to take this examination is not required. It is only necessary for the candidate to proceed in accordance with the following instructions:

Upon the decision of the candidate that he is desirous of entering and can fulfill the requirements of a position in the Corps of Civil Engineers, United States Navy, he should fill in the blank spaces of the notification blank provided on page 8 as directed, detach the sheet, and mail it to the Bureau of Yards and Docks, Navy Department, Examining Board, Washington, D. C. This should be done immediately as it will be to the candidate's interest to get this notification blank to the examining board as soon as possible.

To compete in this examination it is only necessary for the candidate to address a letter to the Bureau of Yards and Docks, Navy Department, Examining Board, Washington, D. C., inclosing the following information:

(1) Name in full.
(2) Present address.
(3) Legal residence (voting place).

(5) Occupation.
(6) Place and date of birth.
(6) Height and weight.
(7) Photograph. Mark at bottom of front date taken, age (July 1, 1917), height, and weight.
(8) Evidence of American citizenship (birth certificate or affidavit as to native birth or naturalization).
(9) College or university from which graduated, date of graduation, course pursued, length of course, and degree conferred.
(10) Not less than three testimonials in regard to character and moral fitness.
(11) Not less than three testimonials from instructors or professors at the college or university from which the candidate received his degree who were in a position to testify from personal knowledge as to his collegiate work.
(12) Testimonial from employers covering the entire period of the candidate's professional experience.
(13) Statement from the college or university of which candidate is a graduate showing record made separately in all subjects during entire course. If the relative standing in class on graduation can be readily secured, this should also be furnished. The candidate may submit additional information, if he desires, regarding his collegiate work.
(14) Chronological statement in detail of professional experience since graduation. This should be supplemented by statement of professional experience, if any, during vacations.
(15) Six names of persons who, from personal knowledge, are conversant with the candidate's professional ability. At least two, but not more than three, shall be instructors or professors familiar with his collegiate work. The six names given here should be the same as those on notification blank, and there is no objection to candidate submitting the names of the same persons who furnished him testimonials under 10, 11, or 12 of this paragraph.

7. Final Examination.

Candidates who pass the preliminary examination will be notified to appear before the examining board at Washington, D. C., for further examination.

The final merit of candidates will be based on the collegiate and professional record, the oral and written examination, and general fitness.

Candidates will not be examined directly in such subjects as grammar, language, physics, geology, arithmetic, or higher mathematics. The collegiate record will be taken as indicating a knowledge of these branches.

The oral examination will be of short duration and general in character.

The written examination will consume about five days and will comprise such subjects as the following:

Mechanics.
Stresses in structures.
Electrical and mechanical engineering.
Surveying and mapping, including instruments, their use and adjustment.
Construction materials.
Engineering constructions, such as pavements, yard railways, sewers, water distribution, foundations, wharves, quay walls, and workshops.

Sample questions for this examination are not available.

8. Number in Corps.

The Corps of Civil Engineers United States Navy is composed of two grades, "civil engineer" and "assistant civil engineer." Under existing laws the number of civil engineers is limited to 28, with two additional numbers. The number of assistant civil engineers is not fixed but varies with the total number in the Corps. The total strength of the Corps of Civil Engineers varies with the number of officers in the line of the Navy.

9. Rank and Promotion.

Appointees enter the Corps as assistant civil engineers and are commissioned with the rank of lieutenant (junior grade). Officers are advanced to the ranks of lieutenant and lieutenant commander with their running mates in the line; that is, with the line officer whose commission as lieutenant (junior grade) bears the same or next preceding date. This advancement in rank takes place irrespective of whether they have been promoted from assistant civil engineer to the full grade of civil engineer.

Promotions from the grade of assistant civil engineer to the grade of civil engineer are made as vacancies occur. After attaining the grade of civil engineer officers are advanced to the ranks of commander, captain, and rear admiral as vacancies occur.

Officers are required to establish their professional, physical, and moral fitness for promotion before being advanced in rank or promoted in grade.

While it is impossible to make any definite statement regarding the prospects of promotion, it is estimated that under normal conditions appointees commissioned as assistant civil engineer with the rank of lieutenant (junior grade), would be eligible for examination for promotion to the ranks of lieutenant and lieutenant commander in about 4 or 5 years and 12 or 13 years, respectively. Under war conditions promotion may be more rapid.

10. Numbers in Ranks.

The numbers in the ranks of rear admiral, captain, and commander vary with the number of officers commissioned in the corps. At present there are 1 rear admiral, 4 captains, and 9 commanders, with a commissioned strength of 64 officers. The numbers in the ranks of lieutenant commander, lieutenant, and lieutenant (junior grade) are not fixed, officers being advanced in rank with their running mates in the line.

11. Chief of Bureau.

The Chief of the Bureau of Yards and Docks is an appointive office for a term of four years and may be held by any officer of the Corps of Civil Engineers who has had seven years' active service. This office carries with it the rank, pay, and allowances of rear admiral.

12. Pay.

Officers of the Corps of Civil Engineers receive the pay and allowances of their rank, as provided for all commissioned officers of the Navy. The pay of an officer is made up of the base pay for a given rank with longevity increase for a length of service and when the Government quarters are not furnished, an allowance for quarters and for heat and light.

The pay and allowance for the various ranks are as follows:

Lieutenant (junior grade).—Base pay, $2,000 per annum, increased 10 per cent every five years up to maximum of $2,800 yearly. Allowance for quarters, $432 yearly.

Lieutenant.—Base pay, $2,400 per annum, increased 10 per cent every five years up to a maximum of $3,360. Allowance for quarters, $576 yearly.

Lieutenant commander.—Base pay, $3,000 per annum, increased 10 per cent every five years up to maximum of $4,000. Allowance for quarters, $720 yearly.

Commander.—Base pay, $3,500 per annum, increased 10 per cent every five years up to maximum of $4,500. Allowance for quarters, $864 yearly.

Captain.—Base pay, $4,000 per annum, increased 10 per cent every five years up to maximum of $5,000. Allowance for quarters, $1,008 yearly.

Rear admiral.—Pay, $8,000 per annum irrespective of length of service. Allowance for quarters, $1,296 yearly.

The allowance for heat and light, when Government quarters are not furnished, varies with rank and locality. For Washington it varies from approximately $120 per annum for rank of lieutenant (junior grade) to $230 for rank of rear admiral.

Longevity service is total service in the Navy from date of first commission. An officer of the rank of lieutenant commander, with 15 years' total service from date of first commission, would receive $3,900 plus allowances if not occupying Government quarters.

Where Government quarters are provided, heat and light are furnished. A reasonable amount of household furniture is also provided for such quarters. Government quarters are not usually available for the younger officers.

When on duty outside the United States the pay is increased 10 per cent.

Mileage in lieu of all expenses, at the rate of 8 cents per mile, is allowed an officer traveling on official duty within the United States. Outside the country actual expenses are allowed.

13. Retirement and Death Benefits.

Officers are retired at 64 years of age with three-fourths pay of their rank.

If an officer dies as the result of disease or injury incurred in the line of duty, the widow is entitled to a pension, the amount of which varies according to rank; a pension allowance is also made for each child under 16 years of age.

Immediately upon the death of an officer on the active list from wounds or disease not the result of his own misconduct, an amount equal to six months' pay at the rate of pay at the date of his death will be paid to his widow, or if no widow, to his children, or if there are no children, to any other dependent relative of such officer previously designated by him.

14. Sick Benefits.

In case of illness an officer is entitled to medical attendance and hospital accommodation. The only charge is for cost of subsistence while in the hospital. He receives full pay while on the sick list. At naval stations families of officers are also given medical attendance.

15. Leave.

An officer may be granted not to exceed one month's leave with full pay each year. This leave may be allowed to accumulate for four years. The officer has no inherent right to leave, and it is not granted unless the exigencies of the service will permit.

16. Uniform.

In general, officers on duty at a navy yard or naval station are required to wear the naval uniform prescribed for their rank and corps. Service blue, or in warm weather service white, is the uniform required for regular duty. Special full dress, dress, and evening dress uniforms are worn on special occasions. During the war only service uniform is required.

The uniform outfit which an officer will need to secure at the present time upon entrance to the service will include service blue, overcoat, cape, mackintosh, blue cap, white cap, service white, service belt, sword, sword knot, and white cotton gloves. This outfit can be purchased for less than $500.

17. Assignment to Duty.

Assistant civil engineers will be detailed for duty at the various yards and stations in the United States and its possessions as assistants to the senior civil engineer. The localities to which such officers will be assigned can not be stated in advance.

18. Work of the Corps of Civil Engineers.

Officers of the Corps of Civil Engineers are charged with the execution of the duties placed by law and regulations under the cognizance of the Bureau of Yards and Docks, one of the administrative divisions of the Navy Department.

The duties of the Bureau of Yards and Docks comprise all that relates to the design and construction of public works of the Naval Establishment on shore, such as dry docks, marine railways, building ways, harbor works, quay walls, piers, wharves, slips, dredging, landings, floating and stationary cranes, power plants, coaling plants; heating, lighting, telephone, water, sewer, and railroad systems; roads, walks, and grounds; bridges, radio towers, hospitals, shops, barracks, and all buildings, for whatever purpose needed. It provides for the general maintenance of the same, except at the naval proving ground, the naval torpedo station, the naval training stations, the Naval Academy, the naval magazines, naval hospitals, and marine posts. It designs and makes the estimates for the public works after consulting as to their operating features with the bureau or office for whose use they are primarily intended. It has charge of all means of transportation, such as derricks, shears, locomotives, locomotive cranes, cars, motor trucks, and all vehicles, horses, teams, subsistence, and necessary operators and teamsters in the navy yards. It provides the furniture for all buildings except at the naval magazines, hospitals, the Naval Academy, and marine posts.

The corps is a growing one, and its position in the Navy organization is one of prominence. New construction authorized and under way aggregates over $100,000,000. Several million dollars are also expended by the bureau annually for the upkeep of naval property. The work is exceptionally varied and offers an attractive field for able and ambitious young engineers.

19. Notification Blank.

..............................1917.

Bureau of Yards and Docks,
Navy Department, Examining Board,
Washington, D. C.

Gentlemen:

Being desirous of entering the Corps of Civil Engineers of the United States Navy, I am submitting herewith, the following six names of persons who, from personal knowledge, are conversant with my professional ability, at least two, but not more than three, of these persons are instructors or professors familiar with my collegiate work.

Name. Address.

Mr. ....
Mr. ....
Mr. ....
Mr. ....
Mr. ....
Mr. ....

(Signed) ....
(Name in full.)
....
(Place of residence.)
....
(Town and state.)

BULLETIN

OF THE

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Pennsylvania Railroad System

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SCREW-SPIKE AND TIE-PLATE TEST

PENNSYLVANIA RAILROAD SYSTEM.

LABORATORY AND TRACK SERVICE TESTS OF SCREW-SPIKES AND TIE-PLATES.

REPORT OF COMMITTEE.

April 27, 1917.

Mr. Elisha Lee,
General Manager, P. R. R. Co.
Mr. D. F. Crawford,
General Manager, Pennsylvania Lines West.

Dear Sirs:—

Your Committee appointed in June, 1908, for the purpose of investigating the screw-spike as a rail fastening, begs to submit its report of the work done and conclusions reached.

Reports have been submitted to you from time to time reciting the progress of the tests of screw-spikes and tie-plates, at Birmingham, Pa., and Wooster, Ohio. The last report (No. 13) was sent you February 24, 1916.

The present seems an opportune time to recount the knowledge gleaned from the experiments and from laboratory tests.

The behavior of the several types of rail fastenings in the Wooster experiment was the same as in the Birmingham experiment, but owing to the lighter curves and lighter traffic at Wooster the developments were much slower, the track at Wooster after six years' service being in almost precisely the same condition as that at Birmingham after three years' service.

The history of the Birmingham and Wooster experiments is recited in the records which accompany this report, and for track on ties in stone ballast the conclusions reached are as follows:

1. Screw-spikes have no advantage over nail-spikes. When used with clips without tie-plates, the cutting of the rail into the tie permits the rail to slip under the clip, thus widening the gage.

2. No satisfactory device is known for resetting screw-spikes after the thread in the wood has been destroyed. When some of the screw-spikes in the Birmingham experiment became so loose that they could be extracted with the fingers, the committee, after considering the several devices for securing screw-spikes, selected the Lakhovsky split lining (photo, p. 64 of record) and 666 of these devices were applied to loose screw-spikes, at a cost of 6.82c each for material and 9c for labor in oak ties or 7c in pine ties. This device did not prove effective, as the spikes soon became loose again by turning back. It seems evident that there is not sufficient friction between the metal surfaces of the screw and the lining to prevent the spike from turning. The hardwood plug method, which is extensively used abroad, was next tried, using locust plugs of the same shape and size with relation to spike as the wooden plugs used in France. This method was also unsuccessful, the spikes soon becoming loose again. A laboratory test of 32 screw-spikes in plugged holes, and 12 standard nail-spikes driven in oak ties in the ordinary way, showed that the average resistance to extraction was the same for the screw-spikes as for the nail-spikes, viz., 5,000 lbs. At least a part of the plug was always extracted with the spike. The Collet Trenail, which consists of a large hardwood plug threaded on the outside and screwed into the tie, was not considered advisable on account of the injury to the tie by boring holes of such large diameter as is necessary. The Tenax lining was discarded as it is similar to the Lakhovsky and has the same objections. The Thiollier Helical Lining was considered but not adopted for the reason that it cannot be applied to track in service. It was also

thought to have the same objection as the Lakhovsky, viz., that the metal surfaces would not possess sufficient friction to prevent the screw from turning back. [Proceedings American Railway Engineering Association, Vol. 15, 1914, Part 2, p. 265.]

3. The first cost and maintenance cost of track equipped with screw-spikes are both considerably in excess of those of track equipped with nail-spikes, as shown in detail in statement of annual cost of maintenance of Birmingham and Wooster experiments (p. 19 of record). The average first cost, at Birmingham and Wooster, of ties and rail fastenings for 1,000 feet of track with tie-plates and nail-spikes was $1,044, while that of similar track with screw-spikes was $1,782, or an increase of 71 per cent. The universally admitted higher first cost of screw-spike track can only be justified by a corresponding decrease in the cost of maintenance. Such a decrease was not effected in this experiment; on the contrary, the average annual maintenance cost of the nail-spike track was $338, and that of the screw-spike track $593, or an increase of 75 per cent. Where tie-plates were not used (which in heavy service tracks is of course practicable only on straight track on account of the rapid cutting of the rail into the ties on curves) the same relation obtained, though in lesser ratio, the first cost of the nail-spike track being $812 and that of the screw-spike track $1,087, an increase of 33 per cent.; the maintenance of the former $309 and that of the latter $396, an increase of 30 per cent. While derailed equipment has not at any time during the experiment damaged the track sufficiently to throw it out of service, thereby necessitating quick repairs, our record of installation of the screw-spike track indicates that in such a case the time required to repair screw-spike track would be more than 60 per cent. greater than would be required for nail-spike track, with the same number of spikes, and tie-plates of similar pattern, even if ties already bored for the screw-spikes were at hand. In the event of an accident destroying any considerable stretch of track, the avoidance of the delay to traffic which would be occasioned by the excess time required to make repairs with screw-spikes would justify the use of nail-spikes for temporary repairs, and the subsequent application of screw fastenings, with the waste of material involved, would greatly increase the cost of repairing track after wrecks.

4. Cow-hair pads as applied in this test have no value as a protection for the tie, as they were quickly squeezed out from under the tie-plates where the traffic was heavy.

5. The 7 inch by 9 inch by 7/16 inch plate is inadequate for pine ties, or even for oak ties, under the heaviest traffic on the P. R. R., and loblolly or sap pine ties are not suitable for such traffic even with very large tie-plates. The maximum load sustained by a tie-plate under 100-lb. rail is about 45 per cent. of the load imposed by the wheel and, under our heaviest equipment (including dynamic augment and impact), is about 26,000 lbs. on tangents and the outer rail of curves, and 36,000 lbs. on the inner rail of sharp curves.

6. While the 7 inch by 9 inch by 7/16 inch tie-plates were found too small under heavy traffic, it is not determined whether the 7 inch by 13½ inch by ⅝ inch tie-plates or the specially designed wrought- and cast-iron tie-plates of greater area and thickness, for the more uniform distribution of the load, will prove economical and save enough in the less cutting of the tie to pay for the additional cost. The cost of maintenance with screw-spike fastenings and 7 inch by 13½ inch by ⅝ inch tie-plates is greater than with nail fastenings and 7 inch by 9 inch by 7/16 inch tie-plates.

7. Tie-plates when flat and symmetrical cut more rapidly into the tie at the outer edge, thus canting the rail. They therefore should be so designed as to bring the line of thrust as near the center of the plate as practicable.

8. When necessary to slot joint bars to permit the use of clips the slots should be semi-circular in shape, as large rectangular slots weaken the joint bars, causing breakage.

When your Committee inspected the screw-spike track on the Delaware, Lackawanna & Western Railroad and the New York, New Haven & Hartford Railroad, as noted in our 13th report, the maintenance of way officers of these roads stated that screw-spikes were giving entire satisfaction and had been adopted as standard.

It should be borne in mind, however, that new screw-spike track was compared with ordinary nail-spike track, and it is probable that, if a section of the latter had been laid new at the time of the installation of the screw-spike track, its performance would have been as satisfactory as, and its maintenance cost less than, that of the screw-spike track, as was the case at Birmingham and Wooster.

We are advised that the daily traffic over the screw-spike track on the Delaware, Lackawanna & Western Railroad is about 71,000 tons, and on the New York, New Haven & Hartford Railroad about 83,000 tons. The traffic on the experimental track at Birmingham averaged 140,000 tons per day, and at Wooster 53,000 tons per day. As the tonnage at Birmingham is about twice that on the Lackawanna and New Haven roads, it is probable that when the tonnage on the latter roads reaches the total carried by the Birmingham experimental track their results will not be any more favorable than ours to the screw-spike.

The screw-spike track at Greenwich, Conn., New York, New Haven & Hartford Railroad, is now in about the same condition as when inspected by the Committee in November, 1913, except that the cutting of the tie-plates into the ties has increased slightly; the penetration does not exceed ½ inch. Some of the ties show evidence of slight decay, but they all seem good for at least three years' additional service. Most of the screw-spikes are standing up from ¼ to ½ inch clear of the rail and a few are up an inch or more (which does not indicate any superiority of the screw- over the nail-spike). No cases were found where the screw-thread in the tie has been destroyed.

The Delaware, Lackawanna & Western Railroad is now experimenting with a new fastening in which the tie-plate is secured by bolts extending through the tie and a metal plate underneath the tie [Engineering News, 10/19/16, p. 727]. This would seem to indicate that screw-spikes have not proved altogether satisfactory.

Mr. Louis Yager, Acting Engineer Middle West, Northern Pacific Railway, writes [Engineering News, 3/15/17, p. 419] that his company in 1915 began experiments with rail-chairs having bolt fastenings, "the screw-spikes used in the test tracks not having proved very satisfactory."

In conclusion, it may be said that throughout this experiment as elsewhere, it has been evident that there is no danger to traffic from failure of ordinary nail-spikes either by shearing or extraction, and the question of securing greater holding power by the use of screw-spikes is solely a matter of economy, so that in order to justify its use the screw-spike must accomplish a reduction in cost of track maintenance sufficient to offset its higher first cost. This result has not been accomplished—in fact, the screw-spike has not only been more costly to maintain, but also less reliable than the nail-spike, and while it holds better at first, owing to its greater initial resistance to extraction, it becomes entirely loose under continued raising by the undulating action of the rail. The nail-spike under similar circumstances still retains a very considerable portion of its holding power.

Respectfully submitted,

(Signed) W. G. Coughlin, Chairman;
G. W. Creighton, W. C. Cushing, A. C. Shand,
R. Trimble, F. T. Hatch, C. H. Niemeyer,
Committee on Screw-Spike Test.

*SCREW-SPIKES AND TIE-PLATES.

Experiments Conducted by Joint Committee of Pennsylvania System, Lines East and West, 1910 to 1915.

PERSONNEL OF COMMITTEE.

In June, 1908, the General Managers of the Lines East and West (W. W. Atterbury and G. L. Peck) by direction of President James McCrea, appointed a "Joint Committee on Screw-Spike Test" consisting of the following officers:

J. T. Richards, Chief Engineer Maintenance of Way, Pennsylvania Railroad (Chairman); L. R. Zollinger, Engineer Maintenance of Way, Pennsylvania Railroad; G. W. Creighton, General Superintendent, Eastern Pennsylvania Division; R. Trimble, Chief Engineer Maintenance of Way, Northwest System, Pennsylvania Lines West; W. C. Cushing, Chief Engineer Maintenance of Way, Southwest System, Pennsylvania Lines West; T. H. Johnson, Consulting Engineer, Pennsylvania Lines West.

In July, 1913, Mr. Zollinger was appointed Chairman to succeed Mr. Richards and A. B. Clark, Assistant Engineer Maintenance of Way, was added to the membership of the committee. Mr. Zollinger died in October, 1913, and, in February, 1914, W. G. Coughlin, Engineer Maintenance of Way, was appointed Chairman. The vacancy caused by the death of T. H. Johnson, April 15, 1914, was filled by the appointment in May, 1914, of F. T. Hatch, Chief Engineer, Vandalia Lines, and in August of the same year A. C. Shand, Chief Engineer, Pennsylvania Railroad, was added to the membership. The present membership of the committee is as follows:

W. G. Coughlin (Chairman); G. W. Creighton (died June 2, 1917); R. Trimble, W. C. Cushing, A. B. Clark (superseded by C. H. Niemeyer, September 28, 1916); F. T. Hatch, A. C. Shand.

INSTRUCTIONS.

The Committee was instructed to:

†1. Decide upon the type of screw to be tested.
2. Prepare explicit instructions in regard to its application.
3. Map out a common method of recording results obtained as to cost of application (wear, etc.).
4. Select the points for such tests, having in view alignment and grade at which they shall be made. Also any other points and specifications not covered by the above suggestions.

The Committee, at its first meeting, June 16, 1908, decided that, in view of the fact that the screw-spike experiments must be made on curves where tie-plates are used and also on softwood ties requiring tie-plates, it would be desirable to experiment with the various forms of tie-plates in conducting the screw-spike test.

LOCATION.

The locations selected for the experimental track were in No. 1 eastward passenger and freight track east and west of Birmingham, Middle Division, Pennsylvania Railroad, and in No. 1 westward passenger and freight track east of Wooster, Eastern Division, Northwest System, Pennsylvania Lines West. (See insert pp. 32 and 33.)

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*Record compiled by J. Craig Crawford, Assistant Engineer, Pennsylvania Railroad.

†Proceedings, American Railway Engineering Association, Vol. 10, Part 2, 1909.

TYPES OF TIE-PLATES AND FASTENINGS.

[*]After a very thorough investigation of the experience of foreign railroads with screw-spikes, plans were prepared for seven types of rail fastenings, Nos. 1, 4, 6 and 7 to be used on oak and pine ties, Nos. 2 and 3 (without tie-plates) to be used on oak ties only. No. 5 was eliminated. All ties to be creosoted and one-half of each section to be laid with cow-hair pads. (See insert page 32 for sketches of various types, pp. 31 to 36 inc. for detail plans of the tie-plates, spikes, etc., and pp. 37 to 43 for photos of the several types of track.) Detailed instructions for the installation and inspection of the experimental track, and blanks for reports were prepared (See pp. 43 to 51).

INSTALLATION.

During November and December, 1909, and January, 1910, the track at the adopted location east and west of Birmingham, Pa., was prepared by putting in fresh ballast, preparing for thorough drainage, etc., and ten sections of experimental track, each 1,000 feet long, were installed as shown and described on location plan on insert page 32, and signboards bearing a description of material and appliances were erected at each end of each section. During the last eight months of 1910 the same was done east of Wooster, Ohio. Some bad ties were used in the Birmingham track, as follows:

Type	1a	1b	2	3	4a	4b	6a	6b	7a	7b	Ttl.
Split	4	..	..	17	1	1	1	1	1	..	26
Soft	1	..	..	2	..	..	..	1	..	..	4
Wind Shaken	.	1	2	2	..	..	..	4	1	..	10
Decayed Heart	.	..	..	1	..	..	3	..	1	..	5
Bad Knot	.	..	1	..	..	..	..	..	..	..	1
Transverse Crack	.	..	..	..	..	..	..	..	1	..	1
Total	5	1	3	22	1	1	4	6	4	..	47

The bad ties in types 2, 3, 4a and 4b, 6a and 6b, remained until these types were eliminated from the experiment—types 4a and 4b in October, 1911, types 2 and 3 in April, 1913, and types 6a and 6b in May, 1914. Those in type 1b were renewed in January, 1913, type 1a in August, 1913, and type 7a in November, 1913.

In less than a month after installation the cow-hair pads began to be squeezed out from under the tie-plates in the Birmingham track and in six months they were nearly all out. (See photos, pp. 52, 53, 54 and 55.)

PERFORMANCE OF EACH TYPE.

Birmingham Service Test.

Type 1a—Birmingham—Standard track with standard 7 inch by 9 inch by 7/16 inch tie-plates and standard nail spikes. Oak tie. Installed November, 1909.

No deterioration of any kind for one year eight months, when ties began to show cutting under outer edge of tie-plates on inner side of cure. This cutting continued, and one year later it was found necessary in some places to adze the ties under the low rail. On 52 of the ties the plates were at that time embedded ⅜ inch or more, and after 3 years and 7 months 69 ties were cut to this extent or more. After four years' three months' service, 87 of the ties were cut ⅜ inch or more, nearly all of the ties on the curve had been adzed, and 10 ties were removed on account of wear. Otherwise track was in good condition until its elimination from the experiment in November, 1914 (five years' service) on account of the rail being changed from 100 lbs. to 125 lbs. section, which involved changing the tie-plates.

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[*] Proceedings, American Railway Engineering Association, Vol. 10, Part 2, 1909.

Type 1b—Birmingham—Standard track with standard 7 inch by 9 inch by 7/16 inch tie-plates and standard nail spikes. Pine ties. Installed November, 1909.

After six months' service, tie-plates began cutting perceptibly into the ties, indicating that the 7 inch by 9 inch tie-plates were too small for softwood ties and, as cutting was much more pronounced under outer edge of tie-plate, it was evident that tie-plates should have outer ends longer than the inner. Accordingly the standard plan of tie-plates on the Lines East was, in January, 1911, changed, increasing the length of tie-plate ¾ inch at the outer end. A similar change had previously been made on the Lines West, the increase being ½ inch. It was apparent that a 7 inch by 9 inch tie-plate was utterly inadequate for pine ties or even for oak ties under the heavy traffic at this point and that pine ties would not be suitable for such locations, even with very large tie-plates. After a service of 2 years and 11 months 232 of the ties (about 40 per cent.) were cut ⅜ inch or more, and in 3 years and 7 months 267 ties were cut this amount. After four years' and three months' service nearly all the ties on the curve had been adzed under the low rail, 175 had been removed on account of wear and 196 others were cut ⅜ inch or more. After 5 years and 5 months 359 ties were cut that amount. In May, 1915, 92 ties were renewed on account of being cut by plates, making a total of 267 renewed for this cause; 48 other ties were renewed in June, 1912, account damage from derailed equipment, at which time 257 other ties were cut. Otherwise track continued in good condition until the conclusion of the experiment, July 31, 1915.

Type 2—Birmingham—Standard track, standard nail spikes, no tie-plates. Oak ties. Installed December, 1909.

After five months the cutting of the ties by the rail was noticeable, but the penetration was only about 3/16 inch after 1 year 7 months' service, and ¼ inch to ⅜ inch after 2 years and 4 months. After 2 years and 10 months, 72 ties were cut ½ inch or more, and 161 ties were cut ⅜ inch to ½ inch after a service of 3 years and 4 months, when (April, 1913) this section was eliminated from the experiment owing to the failure of Type 3 with which it was being compared. The canting of the rail was slight, the gage widening only 3/16 inch.

Type 3—Birmingham—Screw-spikes with rolled clips. No tie-plates. Oak ties. Installed December, 1909.

The rail cut into the ties in the same manner, but not quite as fast as in the case of Type 2. After one year about a dozen of the clips were loose. In two years four months 29 ties were cut ¼ inch to 5/16 inch, 293 clips and 41 spikes were loose, and after 3 years and 4 months 451 clips and 114 spikes were loose. At this time (April, 1913) the rail had penetrated the ties a distance equal to the thickness of the base of the rail at its edge, which permitted the rail to slip under the clips, thus widening the gage. This type was therefore eliminated from the experiment.

Type 4a—Birmingham—Screw-spikes, rolled clips, standard 7 inch by 9 inch by 7/16 inch tie plates. Oak ties. Installed December, 1909.

During the first three months of service 132 of the clips became loose, and in spite of frequent tightening of the spikes, the loosening of the clips increased, and their rattling was quite perceptible in riding over this section of track. After 1 year the cutting of the tie-plates at outer edge into the ties was noted. After 1 year and 7 months 500 clips and

30 of the screw-spikes were loose and could not be tightened. In October, 1911, this type was eliminated, there being 993 loose clips and 60 loose spikes at that time. The tie-plates cut into the ties at the outer edge on the inner side of curve to a slight extent, there being no noticeable difference in this respect between this type and Type 1a.

Type 4b—Birmingham—Screw-spikes, rolled clips, standard 7 inch by 9 inch by 7/16 inch tie-plates. Pine ties. Installed December, 1909.

The behavior of this type was precisely similar to that of Type 4a except that the plates cut more rapidly into the ties and the screw-spikes loosened more quickly. This type was eliminated at the same time as Type 4a (October, 1911), there being 986 loose clips and 181 loose spikes at that time and 185 of the ties being cut by plates ⅜ inch or more.

In July, 1911, photos were taken of ties taken from Birmingham Experiment Track Types 4a and 4b, and split at spike holes. The photos showed that while the holes had been bored one inch below the bottom of the spike as per instructions, the screw threads in the wood were entirely destroyed, there being no appreciable difference between the oak and pine ties. (See pp. 56-58.)

Type 6a—Birmingham—Screw-spikes, malleable iron tie-plate chairs 7 inches by 13 inches by 2 inches; bolts and clips; oak ties. Installed December, 1909.

After three months' service 35 of the screw spikes were found to be slightly loose, and after 18 months the cutting of the plates into the ties became perceptible at the outer edge of plates under inner rail on curve, This type of track shows a higher cost for lining than the others because the bolts must be loosened and retightened after the track is thrown to line. It was noted that the feet of the rail anchors bore against these tie-plates and it was thought that special rail anchors should be designed for types 6a and 6b that will bear against the tie. After a service of 2 years and 3 months 20 ties were cut about ¼ inch on the outer edge of tie-plates under low rail, and 32 of the screw-spikes were loose. In 3 years and 5 months 166 ties were cut ⅜ inch or more and 416 spikes and 24 clips were loose. In February, 1914 (4 years and 1 month service), the cutting of the ties at the outer edge of the plates and the resultant canting of the rail was found to have widened the gage to 4 feet 9¼ inches at some points with full section rail. The question of remedying this condition was fully discussed by the committee, and as there did not seem to be any convenient way of repairing this form of track and it was evident that this particular design was not properly balanced to resist the overturning forces which caused the canting of the rail and cutting of the outer edge of the tie-plates into the ties, it was thought that nothing could be gained by further experiment with it on sharp curves and that a new tie-plate of similar style or type, with more bearing area outside of the rail than inside, should be designed. It was accordingly decided that where the rail is canted sufficiently to make the gage 4 feet 9¼ inches with full section rail these tie-plates should be replaced with standard tie-plates, which was done on 200 ties; 965 of the spikes and 64 of the clips were loose at this time (February, 1914). The whole section was eliminated in May, 1914. Only one tie was renewed on this section. Page 75 shows cutting of outer edge of plate into tie; p. 60 shows wide gage due to canting of rail, and p. 61 shows the results of 4 years' service on ties, tie-plates, spikes, clips and bolts.

Type 6b—Birmingham—Screw-spikes, malleable iron tie-plate chairs 7 inches by 13 inches by 2 inches; bolts and clips. Pine ties. Installed January, 1910.

The same conditions of cutting of ties and canting of rail as noted under Type 6a prevailed on this section except that the cutting was more rapid into the pine ties of this type of track. After a service of 2 years and 3 months 135 of the ties were cut ¼ inch or more, and a few as much as ½ inch, and 11 spikes were slightly loose. In 3 years and 5 months 301 ties were cut ⅜ inch or more and 89 spikes and 28 clips were loose, and in 4 years and 1 month 374 ties were cut ⅜ inch or more and 423 spikes and 96 clips were loose. Same comment as under Type 6a as to higher cost of lining and rail anchors bearing against tie-plates. This section was eliminated from the experiment at the same time as the other (May, 1914). Photos showing cutting of plates into ties and destruction of screw threads in wood, pp. 62 and 63, and 56 and 58. Another effect of the widening of the gage was that the rail wore out about twice as fast on the 6 degree curves Types 6a and 6b, as on the 6 degree curves on Types 1a and 1b (standard tie-plates). When this excessive rapidity of wear was observed, samples of the rail were analyzed and found to be of normal composition, hence the excessive wear was evidently due to wide gage. 423 spikes and 96 clips were loose on Type 6b in February, 1914.

Type 7a—Birmingham—Screw-spikes, rolled steel tie-plates 7 inches by 13½ inches by ⅝ inch. Oak ties. Installed December, 1909.

After eight months' service a few of the screw-spikes (both plate spikes and rail spikes) were found to be loose, and after 2 years and 4 months the tie-plates were observed to be cutting into the ties, eight ties being cut about ¼ inch. Nineteen of the spikes were loose at that time. Six months later (October, 1912) 36 of the spikes were slightly loose and 19 ties were cut ¼ inch to ½ inch but, as on Type 7b (pine ties) some of the spikes were so loose that they could be extracted with the fingers, the Committee considered the question of the best remedy and decided to try the Lakhovsky split lining (see photo page 64, also pp. 65 and 74). The application of these linings cost 9 cents each in oak ties and 7 cents each in pine ties. 459 of these devices were applied on Section 7a and 207 on Section 7b during 1913; they did not prove effective, however, and the spikes equipped with them soon became loose again. See photo p. 75. After a service of 4 years and 2 months 139 of these ties were cut ⅜ inch or more and 430 spikes were loose (including 12 of the 459 that had been equipped with Lakhovsky linings.) It was noted that the cutting of the outer edges of the plates into the ties was canting the rail and widening the gage in the same manner, though not to the same extent, as on Type 6a owing to the lesser thickness of the tie-plate (⅝ inch as against 1-15/16 inches), but as this form of track can be repaired without difficulty it was decided to continue it, adzing the ties when necessary. All the ties on the curve were adzed under the low rail in September, 1914. It was not found necessary to do any adzing under the high rail. At this time 22 of the 459 spikes which had been equipped with Lakhovsky linings were again found loose and there were 275 other loose spikes. Seven months later, after 5 years and 4 months' service (April, 1915) 281 ties were cut ⅜ inch or more and 482 spikes were loose, including a number with Lakhovsky linings, and in June, 1915, 283 ties were cut and 492 spikes were loose.

In June, 1915, the *wooden plug method of re-setting spikes which is extensively used abroad was tried. Locust plugs 1 inch by 1-3/16 inches at the top, ⅞ inch by 1 inch at the bottom, and 5 inches long were used for the rail spike holes and smaller plugs ¾ inch by ⅞ inch at the top, ⅝ inch by 11/16 inch at the bottom and 3¼ inches long, for the plate spike holes, these dimensions bearing the same relation to those of the spikes as the measurements of the wooden plugs used in France bear to the spikes in connection with which they are used. These plugs were driven into the spike holes in ten ties where the spikes had come loose, the holes were re-bored and the spikes re-set. The spikes soon became loose again and a laboratory test was made which showed that the resistance to extraction offered by the screw-spike in the plugged hole was no greater than that of an ordinary nail spike. (For report of test see pages 76-79.) This type of track was accordingly eliminated in August, 1915, at which time there were 358 loose spikes and 264 ties cut by plates. The ties on the curve were adzed under the low rail in September, 1914, to restore the canted rail to its normal perpendicular position. Seven ties were renewed on this section, four of them on account of original defect and three on account of wear.

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*Proceedings, American Railway Engineering Association, Vol. 10, Part 2, p. 1467.

Type 7b—Birmingham—Screw-spikes, rolled steel tie-plates 7 inches by 13½ inches by ⅝ inch. Pine ties. Installed December, 1909.

The service afforded by this type was similar to that of Type 7a except that the softer ties naturally offered less resistance to cutting by plates and loosening of spikes. After a service of 2 years and 4 months 17 of the ties were cut ¼ inch or more and 16 of the spikes were loose. After 2 years and 10 months 63 ties were cut from ¼ inch to ⅝ inch and 49 spikes were loose, several of the latter, particularly at joints, being so loose that they could be extracted with the fingers. (P. 86.)

At this time the Committee considered several methods of re-setting the loose spikes, as follows:

1. The Square Plug.—This was discarded at this time for the reason that it could afford only temporary relief, as the same forces which loosened the spike in the tie would loosen it in the plug.
2. The Thiollier Helical Lining.—Not adopted because it cannot be applied to track in service.
3. The Collet Trenail.—Same objection as the square plug, though it might hold the spike somewhat longer, but it has the additional objection that it has a very large diameter and would therefore inflict too much injury on the tie.
4. The Lakhovsky Split Lining.—This was adopted and 207 spikes were equipped, but in February, 1914, 15 of them were again found loose. At that time 198 ties were cut ⅜ inch or more. In April, 1915, there were 450 cut ties and 582 loose spikes, and in June 541 cut ties and 675 loose spikes. In August, 1915, this type was eliminated. At that time there were 685 loose spikes and 451 ties cut by plates. Five ties were renewed on this section account of wear.

In the Spring of 1911 the rail on the 6 degree curves on Types 1a, 1b, 4a, 4b, 6a and 6b was renewed, when the gage returned precisely to that first reported after the track was installed, thus proving that there had been absolutely no lateral movement of the tie-plates since installation.

During the first 10 months there were 114 joint bar failures on the Birmingham track, of which one was Keystone Insulated, five were standard No. 8a bars, seven had semi-circular slots for screw-spikes (see plan 59582—p. 35) and 101 had rectangular slots for clips (see plan 59702—p. 32). As this showed conclusively that the deep rectangular slotting for the clips was conducive to the fracture of the bar, the design of clips for Types 3, 4 and 6 was revised to permit the slot to be semi-circular (see plan 60109—p. 80).

About 11 months after the experiments were installed, a car loaded with pig metal was derailed by a broken flange west of Section 4a and ran the entire lengths of 4a and 1b, defacing all the ties on both these sections (see photos pp. 81 and 82).

On October 4, 1911, considerable damage was done the Birmingham Experimental Track by a loose wheel on a car in a loaded coal train, as follows:

Type 4b—445 pine ties damaged.
970 screw-spikes and clips.
425 tie-plates.
Type 6a—108 clips and bolts.
16 joint bolts.
78 malleable tie-plates.
Type 6b—432 clips and bolts.
57 joint bolts.
286 malleable tie-plates.
Type 7a—32 screw-spikes.
16 tie-plates.

All the above material required renewal except the ties in Type 4b and the tie-plates in Type 7a. (Photos showing damaged material pp. 83, 84 and 85.)

On May 5, 1914, a truck under a loaded car broke down and was derailed east of Birmingham, damaging the Experimental Track as follows:

Type 1a—182 tie-plates, 469 spikes, 212 oak ties. Not damaged enough to necessitate immediate renewal.
Type 6a—156 tie-plates damaged, replaced; 204 other tie-plates damaged.
Type 6b—90 tie-plates damaged and replaced; 296 other tie-plates damaged.
Type 7a—286 rail spikes damaged and replaced.
538 plate spikes damaged and replaced.
66 tie-plates damaged.
137 oak ties damaged.
Type 7b—620 rail spikes damaged and replaced.
599 plate spikes damaged.
104 tie-plates damaged.

In view of the fact that the removal of the malleable iron tie-plates (Type 6) necessitated the raising of 78 ties on Section 6a and 45 on 6b about 1½ inches higher than the other ties, and these ties being scattered throughout the portions of these sections remaining in track, giving the track a very ragged appearance, and also that all the curved portions of these sections were eliminated from the experiment in February, 1914, on account of widening of gage, the remainder of the two sections (Types 6a and 6b) were eliminated from the experiment in May, 1914, as stated above.

In May, 1912, the Chairman informed the President that the Screw-Spike Experiment had demonstrated that loblolly pine, shortleaf or sap pine ties are only suitable for branches of very light traffic, and that 7 inch by 9 inch tie-plates are too small for main line traffic. The letter follows:

Mr. James McCrea, May 9, 1912.
President.

Dear Sir:

The experimental stretches of track with various fastenings at Birmingham, Pa., and Wooster, Ohio, were visited by the Joint Committee on Screw-Spike Test on April 3rd and 4th and were found very little changed in condition since the inspection of last summer. The most noticeable thing is the embedding of the tie-plates into the ties, and this is especially apparent at Birmingham, where the tonnage for the past year has averaged 141,323 tons per day, as compared with the average of 52,012 tons at Wooster.

The standard tie-plates, 7 inch by 9 inch, are too small for the cheap loblolly or shortleaf pine ties, which were treated with creosote. It is manifest that this variety of wood can only be used under our branches of lightest traffic and in sidings. At Birmingham the oak ties are beginning to show the abrasion of the tie-plates, although this is not serious, while at Wooster there is scarcely any cutting of oak ties noticeable, but it seems probable that the present 7 inch by 9 inch tie-plate will have to be enlarged to give more bearing.

Even the large tie-plates, 7 inch by 13½ inches, like those used in the New York Tunnels (Type No. 7 of test) and the malleable iron chairs 7 inch by 13 inch (Type No. 6 of test) are showing considerable cutting into pine ties and some cutting in the oak ties, although the latter is not serious. It would seem that soft pine ties, even though they are protected with a plate 7 inch by 13 inch, are not going to stand up under our main line traffic, and that for oak ties a plate this size is likely to prove necessary.

The malleable chairs (Type 6) hold the rail so high above the tie that the slight cutting of plate into tie on the outside permits the widening of gage, and this is very difficult to adjust, so that it is likely this type of plate and fastening—at least of the present size and design—will be unsatisfactory, especially as it was the most expensive. It is possible that a shallower plate with a larger area of base might be more satisfactory.

The wide gage has in turn been responsible for excessive wear on the low rail, resulting in the rail giving less life. The fastening was designed to avoid removing screw-spikes from ties when rail was renewed, consequently to remove plate, re-adze tie and replace plate, besides being expensive, would defeat the object of the design.

The experiment with standard tie-plates, screw-spikes and clips (Type 4) has been abandoned, as it was impossible to keep the screw-spikes tight and they are being replaced with driven spikes.

The experiment of screw-spikes and clips without plates (Type 3) seems to slightly retard the cutting of rail into tie, but it is manifest that this type is only suitable for tangents on lines of comparatively light traffic.

In general—with the exception of Type 4—all types of fastenings, after a service of more than two years, are still in fair condition, no one type showing much marked superiority over all the others as to make a solution possible at this time.

In conclusion, it is demonstrated, we think, that the loblolly pine, shortleaf or sap pine ties are only suitable for branches of very light traffic, and that our 7 inch by 9 inch tie-plate is too small for such traffic as we have to-day on the Main Line.

Yours truly,

(Signed) J. T. Richards,
Chief Engineer Maintenance of Way, Chairman, Joint Committee on Screw-Spike Test.

Wooster Service Test.

Type 1a—Wooster—Standard track with standard 7 inch by 9 inch by ⅝ inch Goldie tie-plates and standard nail spikes. Oak ties. Installed May, 1910.

After service of 2 years 11 months, the cutting of the tie-plates at outer edge was quite marked, 10 of the ties being cut ⅜ inch. One year and 3 months later 46 ties were cut ⅜ inch or more and in November, 1914, when this type was eliminated on account of the elimination of the corresponding type at Birmingham 52 ties had been cut ⅜ inch or more.

Type 1b—Wooster—Standard track with standard 7 inch by 9 inch by ⅝ inch Goldie tie-plates and standard nail spikes. Pine ties. Installed July, 1910.

After service of 2 years 3 months, the cutting of tie-plates, at outer edge, into the ties was quite marked, 15 of the ties being cut from ½ inch to ⅝ inch. Six months later 210 of the ties were cut ⅜ inch or more, and after 4 years' service 355 of the ties were cut ⅜ inch or more and two spikes were found broken. In August, 1915, when the experiment was concluded, 440 of the ties were cut ⅜ inch or more and 4 spikes were loose. (Page 88.)

Type 2—Wooster—Standard track; standard nail spikes. No tie-plates. Oak ties. Installed July, 1910.

After 1 year 9 months' service the cutting of the rail into the ties became perceptible, but none of them were cut as much as ¼ inch. At two points it was noticed, at this time, that the rail had pushed the spikes back a little, apparently due to irregularity of surface. The cutting of rail into the ties continued, but gage was not seriously affected, the maximum being 4 feet 8-11/16 inches after service of 2 years 3 months. In April, 1913, when this type was eliminated after a service of 2 years and 9 months on account of the failure of Type 3 in Experimental Track at Birmingham, track was in good condition, none of the ties being cut as much as ⅜ inch and only one spike found standing above the base of rail.

Type 3—Wooster—Screw-spikes, rolled clips. No tie-plates. Oak ties. Installed July, 1910.

After one year's service 4 of the clips were found loose, and 9 months later there were 259 clips and 37 loose spikes. After service of 2 years and 3 months there were 328 loose clips and 69 loose spikes, and in April, 1913 (6 months later), when this type was eliminated on account of the failure of the corresponding type at Birmingham, there were 421 loose clips and 89 loose spikes. None of the ties were cut as much as ⅜ inch at this time. (Page 87.)

Type 4a—Wooster—Standard 7 inch by 9 inch by ⅝ inch Goldie tie-plates. Screw-spikes and slips. Oak ties. Installed December, 1910.

This track was installed a year later than the corresponding type at Birmingham, during which time the tendency of the clips to become loose was noticed and a clip of different design having a shoulder to fit against the base of the rail (see plan 14391, insert page 32) was used. After 7 months' service 50 clips were found loose, and 3 months later there were 365 loose clips and 28 loose spikes; no cut ties. At this time (October, 1911) this type was eliminated on account of the failure of Type 4a at Birmingham.

Type 4b—Wooster—Standard 7 inch by 9 inch by ⅝ inch Goldie tie-plates, screw-spikes and clips. Pine ties. Installed December, 1910.

After 7 months' service 175 clips and 7 spikes were found loose. The improved clip was used on this type as well as on Type 4a. After 10 months' service there were 405 loose clips and 35 loose spikes but no cut ties. This type was then (October, 1911) eliminated on account of elimination of corresponding type at Birmingham.

Types 5a and 5b Wooster—These were special designs of the Lines West, but the results of the test were not recorded herein. (Photos page 89.)

Type 6a—Wooster—Screw-spikes; malleable iron tie-plate chairs 7 inches by 13 inches by 2 inches; bolts and clips. Oak ties. Installed May, 1910.

After service of 1 year 11 months the tie-plates were observed to be cutting slightly into the ties and 4 screw-spikes were found loose. Six months later there were 16 loose spikes and 8 loose clips. After service of 3 years and 1 month 14 of the ties were cut ⅜ inch or more and 195 spikes and 40 clips were loose. In May, 1914, when this type, after 4 years' service was eliminated on account of failure of corresponding type at Birmingham there were 161 loose spikes and 31 cut ties.

Type 6b—Wooster—Screw-spikes, malleable iron tie-plate chairs 7 inches by 13 inches by 2 inches; bolts and clips. Pine ties. Installed November, 1910.

After service of 1 year 5 months the cutting of the tie-plates into the ties was noted, but although considerably more than on Type 6a (which had been in service 7 months longer) it was not over ⅛ inch. Six months later 7 spikes and one clip were loose. After service of 2 years and 7 months 89 ties were cut ⅜ inch or more and 168 spikes and 20 clips were loose. In May, 1914, when, after 4 years' service, this type was eliminated, on account of failure of the corresponding type at Birmingham, there were 32 loose spikes and 240 cut ties.

Type 7a—Wooster—Screw-spikes; rolled steel tie-plates 7 inches by 13½ inches by ⅝ inch. Oak ties. Installed June, 1910.

After service of 1 year 10 months the cutting of tie-plates at outer edge into the ties was noted and 5 spikes were loose; six months later 19 spikes were found loose. After service of 3 years only one tie was cut as much as ⅜ inch. At this time 182 spikes were loose. After 4 years' service there were 16 ties cut ⅜ inch or more and 75 spikes were loose. In August, 1915, when the experiment was concluded, 21 of the ties were cut ⅜ inch or more and 203 spikes were loose.

Type 7b—Wooster—Screw-spikes; rolled steel tie-plates 7 inches by 13½ inches by ⅝ inch. Oak ties. Installed June, 1910.

After service of 1 year 5 months the cutting of tie-plates, at outer edge, into ties was noted and 8 spikes were loose. Six months later 7 of the ties were cut over ¼ inch and 8 spikes were found loose. After service of 2 years and 7 months 52 of the ties were cut ⅜ inch or more and 50 spikes were loose, and 1 year and 1 month later 149 of the ties were cut ⅜ inch or more and 37 spikes were loose. In August, 1915, when the experiment was concluded, 208 of the ties were cut ⅜ inch or more and 124 of the spikes were loose. (Photo. p. 90.)

July 8, 1911, the Experimental Track at Wooster was damaged by a pair of derailed wheels under a loaded coal car. Only six screw-spikes were damaged, but considerable damage was done to the ties.

COST OF INSTALLATION AND MAINTENANCE.

The table below shows that both the annual cost and the cost per million tons traffic are less for the nail spike than for the screw-spike. Reference to the tables following, which state the costs and tonnage of traffic in detail, will show that both first costs and maintenance costs are in favor of the nail spike in all cases. In comparing costs of Types 2 and 3 with the others it must be remembered that these two types are on straight track and oak ties and would not be suitable for curves or softwood ties.

SCREW-SPIKE EXPERIMENT.

Birmingham, Pa., and Wooster, O., March, 1910, to July, 1915, inclusive.

	First Cost			*Annual Cost			†Cost per million tons traffic		
Type	Brghm.	Wstr.	Avge.	Brghm.	Wstr.	Avge.	Brghm.	Wstr.	Avge.
1a	$ 896	$ 1,151	$ 1,023	$ 316	$ 333	$ 324	$ 5.48	$ 15.64	$ 10.56
1b	912	1,218	1,065	355	350	352	6.31	16.38	11.39
2	765	860	812	344	274	309	6.00	12.56	9.28
3	1,018	1,156	1,087	443	350	396	8.05	16.60	12.32
4a	1,286	1,627	1,456	940	452	696	17.96	21.67	19.81
4b	1,181	1,676	1,428	876	466	671	16.90	22.26	19.58
6a	2,384	2,457	2,420	757	607	682	14.74	31.74	23.24
6b	2,361	2,450	2,405	759	592	675	14.80	30.98	22.89
7a	1,556	1,477	1,516	460	388	424	8.25	19.23	13.74
7b	1,473	1,462	1,467	435	390	412	7.84	19.35	13.59
Total	$13,832	$15,536	$14,684	$5,685	$4,202	$4,943	$106.33	$206.41	$156.37
Average	$ 1,383	$ 1,554	$ 1,468	$ 569	$ 420	$ 494	$ 10.63	$ 20.64	$ 15.64

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*Interest at 6 per cent. and taxes at 1 per cent. (both on first cost in track), plus cost of maintenance, plus annuity, which, at 6 per cent. compound interest will amount at end of life to first cost in track less salvage.

†Including installation and maintenance.

M. W. Exp.—D.

PENNSYLVANIA RAILROAD SYSTEM

Record of Cost of Maintenance of Experimental Track at Birmingham, pa.,

Month of July, 1915.

TYPE OF TRACK	SURFACING	LINING	GAUGING	Tightening Rail Fastenings	Renewing Rail Fastenings	Tightening Joint Bolts	Renewing Joint Bolts	TOTAL LABOR	COST OF MATERIAL USED IN RENEWAL	GRAND TOTAL
FOR MONTH										
1-a		Eliminated November, 1914.								
1-b										
2		Eliminated April, 1913.								
3		"		"	"					
4-a		"	October, 1911.							
4-b		"		"	"					
6-a		"	February, 1914.							
6-b		"		"	"					
7-a										
7-b										
TOTAL TO DATE	5 yrs. 5 mos.		(1a - 4 yrs. 8 mos. (2 & 3 - 3 " 2 " (4a & 4b - 1 " 8 " (6a & 6b - 4 " 0 "							
1-a	363.00	40.47	33.25	6.84	0.36	13.26	1.71	458.89	23.40	482.29
1-b	497.09	34.89	57.50	26.52		42.18		658.18	227.07	885.25
2	209.00	18.80		5.70		14.21	0.38	248.09	1.39	249.48
3	280.18	18.80		35.14		7.75	1.90	343.77		343.77
4-a	191.33	13.30		46.16	1.33	3.99		256.11	6.67	262.78
4-b	201.74	13.86		47.49	2.28	4171	1.90	271.98	4.30	276.28
6-a	548.84	45.40		94.76	12.73	35.49	2.85	740.07	37.67	777.74
6-b	593.68	17.10		97.04	14.44	33.40	6.08	761.74	51.57	813.31
7-a	378.53	18.10	47.36	112.87	26.58	18.01		601.45	191.20	792.65
7-b	473.65	31.30	27.04	110.69	7.02	17.82	1.90	669.42	89.04	758.46

NOTE:—This record to be compiled monthly, in duplicate, in office of Chief Engineer Maintenance of Way and copies furnished to Chief Engineers Maintenance of Way, Lines East and West.

The cost of labor and material used in connection with crosstie or rail and splice renewals not to be included, except in case of splice bars failing by reason of special slotting.

M. W. Exp.—D.

PENNSYLVANIA RAILROAD SYSTEM

Record of Cost of Maintenance of Experimental Track at Wooster, Ohio.

Month of July, 1915.

TYPE OF TRACK	SURFACING	LINING	GAUGING	Tightening Rail Fastenings	Renewing Rail Fastenings	Tightening Joint Bolts	Renewing Joint Bolts	TOTAL LABOR	COST OF MATERIAL USED IN RENEWAL	GRAND TOTAL
FOR MONTH										
1-a	7.30							7.30		7.30
1-b	7.30							7.30		7.30
2										Nothing
3										Nothing
4-a	16.40							16.40		16.40
4-b	16.40							16.40		16.40
6-a	10.75							10.75		10.75
6-b	10.75							10.75		10.75
7-a										Nothing
7-b										Nothing
5-A	14.60							14.60		14.60
5-B	14.60							14.60		14.60
TOTAL TO DATE										
4 yrs. 7 mos.										
1-a	219.70	1.25	–	.95	.47	8.35	.70	231.42	3.90	235.32
1-b	199.05	12.80	–	1.05	1.72	9.05	–	223.67	9.60	233.27
2	230.49	–	22.10	–	–	–	–	252.59	–	252.59
3	304.10	–	–	11.11	–	–	–	315.21	–	315.21
4-a	234.40	3.60	–	36.75	.37	3.90	–	279.02	13.73	292.75
4-b	223.95	3.60	–	43.40	.37	3.90	–	275.22	21.71	296.93
6-a	308.35	3.40	–	23.85	.72	11.15	–	347.47	4.76	352.23
6-b	248.45	7.00	–	22.60	.15	13.10	–	291.30	.86	292.16
7-a	197.70	7.00	–	18.17	–	3.35	–	226.22	–	226.22
7-b	200.45	10.70	–	21.15	.18	3.70	–	236.18	16.22	252.40
5-A	213.30	8.00	.17	49.35	–	2.60	–	273.42	–	273.42
5-B	238.05	5.00	–	57.00	–	2.45	–	303.40	–	303.40

NOTE:—This record to be compiled monthly, in duplicate, in office of Chief Engineer Maintenance of Way and copies furnished to Chief Engineers Maintenance of Way, Lines East and West.

M. W. Exp.-D

PENNSYLVANIA RAILROAD SYSTEM

Record of Cost of Maintenance of Experimental Track at Birmingham, pa., and at Wooster, O.

ANNUALLY.

July 31,1915.

TYPE OF TRACK	SURFACING	LINING	GAUGING	Tightening Rail Fastenings	Renewing Rail Fastenings	Tightening Joint Bolts	Renewing Joint Bolts	TOTAL LABOR	COST OF MATERIAL USED IN RENEWAL	GRAND TOTAL
Yrs. Mos.			BIRMINGHAM.							
4 " 8 " 1-a	77.73	8.66	7.12	1.46	0.08	2.84	0.37	98.26	5.01	103.27
5 " 5" 1-b	91.72	6.44	10.61	4.89		7.78		121.44	41.89	163.33
3 " 2 " 2	65.93	5.93		1.80		4.48	.12	78.26	.44	76.70
3 " 2 " 3	88.39	5.93		11.08		2.44	.60	108.44		108.44
1 " 8 " 4-a	114.57	7.96		27.64	.80	2.39		153.36	3.99	157.35
1 " 8 " 4-b	120.80	8.30		28.44	1.36	2.82	1.14	162.86	2.58	165.44
4 " 0 " 6-a	137.21	11.35		23.69	3.18	8.88	.71	185.02	9.42	194.44
4 " 0 " 6-b	148.42	4.28		24.26	3.61	8.35	1.52	190.44	12.89	203.33
5 " 5 " 7-a	69.84	3.34	8.74	20.83	4.90	3.32		110.97	35.28	146.25
5 " 5" 7-b	87.39	5.78	4.99	20.42	1.29	3.29	.35	123.51	16.43	139.94

WOOSTER.

Yrs. Mos.

4 " 7 " 1-a	47.97	0.27		0.21	0.10	1.83	0.15	50.53	0.85	51.38
" " 1-b	43.46	2.79		.23	.38	1.98		48.84	2.09	50.93
" " 2	50.32		4.83					55.15		55.15
" " 3	66.40			2.42				68.82		68.82
" " 4-a	51.18	.79		8.02	.08	.85		60.92	3.00	63.92
" " 4-b	48.90	.79		9.47	.08	.85		60.09	4.74	64.83
" " 6-a	67.33	.74		5.21	.16	2.43		75.87	1.04	76.91
" " 6-b	54.25	1.53		4.93	.03	2.86		63.60	.19	63.79
" " 7-a	43.16	1.53		3.97		.73		49.39		49.39
" " 7-b	43.76	2.34		4.62	.04	.81		51.57	3.54	55.11

NOTE :—This record to be compiled monthly, in duplicate, in office of Chief Engineer Maintenance of Way and copies furnished to Chief Engineers Maintenance of Way, Lines East and West.

The cost of labor and material used in connection with crosstie or rail and splice renewals not to be included, except in case of splice bars failing by reason of special slotting.

Record of Tonnage over Screw Spike Test Track
Birmingham, Pa. and Wooster, Ohio.

		Number of Trains						Tonnage					
		Per Month			Per Day			Per Month			Per Day		
1910		Frt.	Pass.	F.&P.	Frt.	Pass.	F.&F.	Freight	Passngr.	Frt.&P.	Freight	Pasngr	F. & P.
3	Birmingham	1788	997	2785	41.5	32.2	73.7	2917838	543625	3461463	94123.8	17536.3	111660.1
4	"	1061	938	1999	35.4	31.3	66.6	2137968	509891	2647859	71265.6	16996.4	88262.0
5	"	1128	969	2097	36.4	31.3	67.6	2888696	528379	3417075	93183.7	17044.5	110228.2
6	"	1127	936	2063	37.6	21.2	66.5	2857921	510012	3367933	95264.0	16452.0	108643.0
7	"	1169	962	2131	37.7	31.0	68.7	3118639	524579	3643218	100601.3	16921.9	117523.2
8	"	1367	1019	2386	44.1	32.9	77.0	3788244	555661	4343905	122201.4	17924.5	140126.0
9	"	1,402	987	2,389	46.7	32.9	79.6	3,815,273	538,213	4,353,486	127,175.8	17,940.4	145,116.2
10	"	1,307	1,023	2,330	42.2	33.0	75.2	3,883,993	557,851	4,441,844	125,290.1	17,995.2	143,285.3
11	"	1,301	1,011	2,312	43.4	33.7	77.1	3,721,683	550,759	4,272,442	124,056.1	18,358.6	142,414.7
12	"	1,429	1,132	2,561	46.1	36.5	82.6	3,466,927	617,285	4,084,212	111,836.4	19,912.4	131,748.8
	1911												
Jan.	Birmingham	1,298	1,071	2,369	41.9	34.6	7.6.4	3,496.981	584,023	4,081,004	112,805.8	18,839.5	131,645.3
	Wooster	1,085	539	1,624	35.0	17.4	52.4	1,262,857	182,135	1,444,992	40,737.3	5,875.3	46,612.6
Feb.	Birmingham	1,135	961	2,096	40.5	34.3	74.9	3,240,905	524,135	3,765,040	115,746.6	18,719.1	134,465.7
	Wooster	794	450	1,244	28.4	16.3	44.4	942,063	150,614	1,092,677	33,645.1	5,379.1	39,024.6
Mar.	Birmingham	1,255	1,083	2,338	40.5	34.9	75.4	3,730,001	590,565	4,320,566	120,322.6	19,050.5	139,373.1
	Wooster	902	470	1,372	29.1	15.2	44.2	1,369,777	254,302	1,624,079	44,186.0	8,203.3	52,389.7
		Freight		Passenger		Frt. & Pass.		Freight		Passenger		Freight & Passenger	
To Date	Brmnghm	16,267		13,089		29,356		43,065,069		7,134,978		50,200,047	
	Wooster	2,781		1,459		4,240		3,574,697		587,051		4,161,748	
Apr.	Brmnghm	1,190	1,032	2,222	39.7	34.4	74.1	3,450,255	562,752	4,013,007	115,008.5	18,758.4	133,766.9
	Wooster	875	447	1,322	29.2	14.9	44.1	1,374,860	229,848	1,604,708	45,828.7	7,661.4	53,490.3
May	Brmnghm	1,217	988	2,205	39.3	31.9	71.1	3,734,060	538,771	4,272,831	120,453.6	17,383.0	137,833.3
	Wooster	834	463	1,297	26.8	15.0	41.8	1,240,313	250,827	1,491,140	40,010.1	8,091.0	48,101.3
June	Brmnghm	1,134	963	2,097	37.8	32.1	69.9	3,401,523	525,131	3,926,654	113,717.4	17,504.4	130,888.4
	Wooster	784	450	1,234	26.1	15.0	41.1	1,100,415	283,908	1,384,323	36,680.5	9,463.9	46,477.1
		Freight		Passenger		Frt. & Pass.		Freight		Passenger		Freight & Passenger	
To Date	Brmnghm	19,808		16,072		35,880		53,650,907		8,761,632		62,412,539	
	Wooster	5,274		2,819		8,093		7,290,285		1,351,634		8,641,919	
July	Brmnghm	1,111	999	2,100	35.9	32.2	67.7	3,291,027	544,762	3,835,789	106,162.2	17,573.0	123,735.1
	Wooster	822	465	1,287	26.5	15.0	41.5	1,219,470	292,587	1,512,057	39,337.9	9,438.2	48,776.1
Aug.	Brmnghm	1,159	1,025	2,184	37.4	33.1	70.4	3,564,690	558,936	4,123,626	114,990.0	18,030.2	133,020.3
	Wooster	883	473	1,356	28.5	15.2	43.7	1,297,213	294,439	1,591,652	41,845.6	9,498.0	51,343.6
Sep.	Brmnghm	1,152	990	2,142	38.4	33.0	71.4	3,468,346	539,847	4,008,193	115,611.5	17,994.9	133,606.4
	Wooster	900	458	1,358	30.0	15.2	45.2	1,325,302	296,608	1,621,910	44,176.7	9,886.9	54,063.6
		Freight		Passenger		Frt. & Pass.		Freight		Passenger		Freight & Passenger	
To Date	Brmnghm	23,230		19,086		42,316		63,974,970		10,405,177		74,380,147	
	Wooster	7,879		4,215		12,094		11,132,270		2,235,268		13,367,538	
Oct.	Brmnghm	1,245	1,010	2,255	40.2	32.6	72.7	3,851,732	551,763	4,403,495	124,249.4	17,798.8	142,048.2
	Wooster	995	512	1,507	32.0	16.5	48.6	1,340,781	306,380	1,647,161	43,251.0	9,883.2	53,134.2
Nov.	Brmnghm	1,315	990	2,305	43.8	33.0	76.8	3,798,941	539,832	4,338,773	126,631.4	17,994.4	144,625.8
	Wooster	852	504	1,356	28.4	16.8	45.2	1,246,881	302,271	1,549,152	41,562.7	10,075.7	51,638.4
Dec.	Brmnghm	1,346	1,050	2,396	43.4	33.9	77.3	3,995,022	572,570	4,567,592	128,871.7	18,470.0	147,341.7
	Wooster	957	533	1,490	30.9	17.2	48.2	1,384,959	322,421	1,707,380	44,676.1	10,400.7	55,076.8
		Freight		Passenger		Frt. & Pass.		Freight		Passenger		Freight & Passenger	
To Date	Brmnghm	27,136		22,136		49,272		75,620,665		12,069,342		87,690,007	
	Wooster	10,683		5,764		16,447		15,104,891		3,166,340		18,271,231	

Record of Tonnage over Screw Spike Test Track. Birmingham, Pa. and Wooster, Ohio.

1912		Number of Trains						Tonnage					
		Per Month			Per Day			Per Month			Per Day		
		Frt.	Pass.	F.&P.	Frt.	Pass	F.&P.	Freight	Pasngr	F. & P.	Freight	Pasngr	F. & P.
Jan.	Birmingham	1495	1035	2530	48.2	33.4	81.6	3,855,796	564,385	4,420,181	124,380.5	18,206.0	142,586.5
	Wooster	996	537	1533	32.1	17.3	49.4	1,319,717	324,841	1,644,558	42,571.5	10,478.7	53,050.3
Feb.	Birmingham	1445	955	2400	49.8	32.9	82.8	3,777,404	520,762	4,298,166	130,255.3	17,957.3	148,212.6
	Wooster	955	491	1446	32.9	16.9	49.8	1,286,787	297,011	1,583,798	44,371.9	10,241.7	54,613.6
Mar.	Birmingham	1533	1012	2545	49.4	32.6	82.1	4,613,482	551,837	5,165,319	148,822.0	17,801.2	166,623.2
	Wooster	1069	515	1584	34.5	16.6	51.1	1,584,765	311,306	1,896,071	51,121.5	10,042.1	61,163.6
To Date		Freight	Passenger		Frt. & Pass.			Freight		Passenger		Freight & Passenger	
	Birmingham	31,609	25,138		56,747			87,867,347		13,706,326		101,573,673	
	Wooster	13,703	7,307		21,010			19,296,160		4,099,498		23,395,658	
Apr.	Birmingham	1202	964	2166	40.1	32.1	72.2	3,586,608	525,668	4,112,276	119,553.6	17,522.3	137,075.9
	Wooster	842	474	1316	28.0	15.8	43.8	1,152,126	285,364	1,437,490	38,404.2	9,512.1	47,916.3
May	Birmingham	1323	999	2322	42.7	32.2	74.9	3,976,253	543,659	4,519,912	128,266.2	17,537.4	145,803.6
	Wooster	875	495	1370	28.2	15.9	44.1	1,458,284	298,027	1,756,311	47,041.4	9,613.7	56,655.1
Jun.	Birmingham	1219	1008	2227	40.6	33.6	74.2	3,657,544	549,662	4,207,206	121,918.1	18,322.1	140,240.2
	Wooster	925	482	1407	30.3	16.0	46.3	1,463,901	289,025	1,752,926	48,796.7	9,634.2	58,430.9
To Date		Freight	Passenger		Frt. & Pass.			Freight		Passenger		Freight & Passenger	
	Birmingham	35,353	28,109		63,462			99,087,752		15,325,315		114,413,067	
	Wooster	16,345	8,758		25,103			23,370,471		4,971,914		28,342,385	
Jul	Birmingham	1219	1010	2229	39.3	32.6	71.9	3,617,574	550,753	4,168,327	116,695.9	17,766.2	134,462.1
	Wooster	876	495	1371	28.3	15.9	44.2	1,461,283	297,934	1,759,217	47,138.1	9,610.8	56,748.9
Aug.	Birmingham	1274	1063	2337	41.1	34.3	75.4	3,895,989	579,654	4,475,643	125,677.1	18,698.5	144,375.5
	Wooster	890	488	1378	28.7	15.7	44.5	1,561,031	293,710	1,854,741	50,355.8	9,474.5	59,830.3
Sep.	Birmingham	1186	1027	2213	39.5	34.2	73.7	3,705,697	560,023	4,265,720	123,523.2	18,667.4	142,190.6
	Wooster	845	474	1319	28.1	15.8	44.0	1,372,639	285,348	1,657,987	45,754.6	9,511.6	55,266.2
To Date		Freight	Passenger		Frt. & Pass.			Freight		Passenger		Freight & Passenger	
	Birmingham	39,032	31,209		70,241			110,307,012		17,015,745		127,322,757	
	Wooster	18,956	10,215		29,171			27,765,424		5,848,906		33,614,330	
Oct.	Birmingham	1442	1036	2478	46.5	33.4	79.9	4,420,481	564,931	4,985,412	142,596.1	18,223.6	160,819.7
	Wooster	991	516	1507	32.0	16.7	48.6	1,575,518	310,632	1,886,150	50,823.2	10,020.4	60,843.5
Nov.	Birmingham	1418	1001	2419	47.3	33.4	80.6	4,209,454	545,845	4,755,299	140,315.1	18,194.8	158,510.0
	Wooster	962	510	1472	32.1	17.0	49.1	1,491,540	307,020	1,798,560	49,718.0	10,234.0	59,952.0
Dec.	Birmingham	1537	1060	2597	49.6	34.2	83.8	4,460,067	578,018	5,038,085	143,873.1	18,645.7	162,518.8
	Wooster	1023	525	1548	33.0	16.9	49.9	1,714,504	316,050	2,030,554	55,306.6	10,195.2	65,501.7
To Date		Freight	Passenger		Frt. & Pass.			Freight		Passenger		Freight & Passenger	
	Birmingham	43,429	34 306		77 735			123,397,014		18,704,539		142,101,533	
	Wooster	21,932	11,766		33,698			32,546,986		6,782,608		39,329,594	
Jan.	Birmingham	1572	1014	2586	50.7	32.7	83.4	4,563,024	552,935	5,115,959	147,194.3	17,836.6	165,030.9
	Wooster	1046	516	1562	33.7	16.7	50.4	1,667,269	310,632	1,977,901	53,782.9	10,020.4	63,803.3
Feb.	Birmingham	1466	924	2390	52.4	33.0	85.4	4,264,414	503,857	4,768,271	152,300.5	17,994.9	170,295.4
	Wooster	978	450	1428	34.9	16.1	51.0	1,532,881	270,900	1,803,781	54,745.8	9,675.0	64,420.8
Mar.	Birmingham	1492	1044	2536	48.1	33.7	81.8	4,595,624	569,293	5,164,917	148,245.9	18,364.3	166,610.2
	Wooster	839	396	1235	27.1	12.8	39.8	1,380,169	238,392	1,618,561	44,521.6	7,690.1	52,211.6
To Date		Freight	Passenger		Frt & Pass.			Freight		Passenger		Freight & Passenger	
	Birmingham	47,959	37,288		85,247			136,820,076		20,330,624		157,150,700	
	Wooster	24,795	13,128		37,923			37,127,305		7,602,532		44,729,837	

Record of Tonnage over Screw Spike Test Track
Birmingham, Pa. and Wooster, Ohio.

1913		Number of Trains						Tonnage					
		Per Month			Per Day			Per Month			Per Day		
		Frt.	Pass.	F.&P.	Frt.	Pass.	F&P.	Freight	Passenger	Frt. & Pass.	Freight	Pass.	Frt.&Pass.
Jan.	Birmingham	1572	1014	2586	50.7	32.7	83.4	4,563,024	552,935	5,115,959	147,194.3	17,836.6	165,030.9
	Wooster	1046	516	1562	33.7	16.7	50.4	1,667,269	310,632	1,977,901	53,782.9	10,020.4	63,803.3
Feb	Birmingham	1466	924	2390	52.4	33.0	85.4	4,264,414	503,857	4,768,271	152,300.5	17,994.9	170,295.4
	Wooster	978	450	1428	34.9	16.1	51.0	1,532,881	270,900	1,803,781	54,745.8	9.675.0	64,420.8
Mar.	Birmingham	1492	1044	2536	48.1	33.7	81.8	4,595,624	569,293	5.164,917	148,245.9	18,364.3	166,610.2
	Wooster	839	396	1235	27.1	12.8	39.8	1,380,169	238,392	1,618,561	44,521.6	7,690.1	52,211.6
* To Date	Birmingham	47,959	37,288	85,247	42.6	33.1	75.6	136,820,076	20,330,624	157,150,700	121,402.0	18,039.6	139,441.6
	Wooster	24,795	13,128	37,923	30.2	16.0	46.2	37,127,305	7,602,532	44,729,837	45,222.0	9,260.1	54,482.1
Apr.	Birmingham	1356	1053	2409	45.2	35.1	80.3	4,055,002	574,201	4,629,203	135,166.7	19,140.0	154,306.7
	Wooster	900	430	1330	30.0	14.3	44.3	1,587,468	258,860	1,846,328	52,915.6	8,628.7	61,544.3
May	Birmingham	1413	1042	2455	45.6	33.6	79.2	4,178,642	568.203	4,746,845	134,794.9	18,329.1	153,124.0
	Wooster	920	470	1390	29.7	15.1	44.8	1,547,170	282,940	1.830,110	49,908.7	9.127.1	59,035.8
Jun.	Birmingham	1303	962	2265	43.4	32.1	75.5	3,916,918	524,579	4,441,497	130,563.9	17.486.0	148,049.9
	Wooster	874	478	1352	29.1	15.9	45.1	1,441,788	287,756	1,729,544	48,059.6	9.591.9	57,651.5
* To Date	Birmingham	52,031	40,345	92,376	42.7	33.1	75.8	148,970,638	21,997,607	170,968,245	122,307.9	18,060.4	140,368.3
	Wooster	27,489	14,506	41,995	27.4	14.4	41.8	41,703,731	8,432,088	50,135,819	45,727.8	9,245.7	54,973.5
Jul.	Birmingham	1381	1099	2480	44.5	35.5	80.0	4,224,815	599,285	4,824,100	136,284.3	19,331.8	155,616.1
	Wooster	876	489	1365	28.2	15.8	44.0	1,441,888	299,456	1,741,344	46,512.5	9,659.9	56,172.4
Aug.	Birmingham	1231	1061	2292	39.7	34.2	73.9	3,880,156	578,563	4,458,719	125,166.3	18,682.7	143,849.0
	Wooster	900	475	1375	29.0	15.3	44.3	1,443,996	287,576	1,731,572	46,580.5	9,276.7	55,857.2
Sep.	Birmingham	1206	1069	2275	40.2	35.6	75.8	3 728,293	582,926	4,311,219	124,276.4	19,430.9	143,707.3
	Wooster	871	474	1345	29.0	15.8	44.8	1,431,959	285,258	1,717,217	47,732.0	9,508.6	57,240.6
* To Date	Birmingham	55,849	43,574	99,423	42.6	33.3	75.9	160,803,902	23,758,381	184,562,283	122,751.1	18,136.2	140,887.3
	Wooster	30,136	15,944	46,080	30.0	15.9	45.9	46,021,574	9,304,378	55,325,952	45,838.2	9,267.3	55,105.5
Oct.	Birmingham	1361	1121	2482	43.9	36.2	80.1	4,315,437	611,281	4,926,718	139,207.6	19,718.8	158,926.4
	Wooster	935	522	1457	30.2	16.8	47.0	1,497,435	314,244	1,811,679	48,304.4	10,136.9	58,441.3
Nov.	Birmingham	1287	1047	2334	42.9	34.9	77.8	3,954,541	570,929	4,525,470	131,818.0	19,031.0	150,849.0
	Wooster	891	496	1387	29.7	16.5	46.2	1,357,442	298,592	1,656,034	45,248.0	9,953.1	55,201.1
Dec.	Birmingham	1309	1129	2438	42.2	36.4	78.6	4,028,268	615,644	4,643,912	129,944.1	19,859.4	149,803.5
	Wooster	784	511	1295	25.3	16.5	41.8	1,406,076	307,622	1,713,698	45,357.3	9,923.3	55,280.6
* To Date	Birmingham	59,806	46,871	106,677	42.7	33.4	76.1	173,102,148	25,556,235	198,658,383	123,468.0	18,228.4	141,696.4
	Wooster	32,746	17,473	50,219	29.9	15.9	45.8	50,282,527	10,224,836	60,507,363	45,878.2	9,329.2	55,207.4

* Birmingham from Mar. 1. 1910; Wooster from Jan. 1. 1911.

Record of Tonnage over Screw Spike Test Track
Birmingham, Pa. and Wooster, Ohio.

1914		Number of Trains						Tonnage					
		Per Month			Per Day			Per Month			Per Day		
		Frt.	Pass.	F. & P.	Frt.	Pass	F&P.	Freight	Passenger	Frt. & Pass.	Freight	Pass.	Frt. & Pass.
Jan.	Birmingham	1337	1074	2411	43.1	34.6	77.7	3,931,527	585,652	4,517,179	126,823.5	18,892.0	145,715.5
	Wooster	782	499	1281	25.2	16.1	41.3	1,354,059	300,398	1,654457	43,679.3	9.690.3	53,369.6
Feb.	Birmingham	1128	982	2110	40.3	35.1	75.4	3,343,797	535,485	3,879,282	119,421.3	19,124.5	138,545.8
	Wooster	675	447	1122	24.1	16.0	40.1	1,124,954	269,094	1,394,048	40,176.9	9,610.5	49,787.4
Mar.	Birmingham	1302	1014	2316	42.0	32.7	74.7	3,938,355	552,934	4,491,289	127,043.7	17,836.6	144,880.3
	Wooster	720	482	1202	23.2	15.6	38.8	1,469,994	290,164	1,760,158	47,419.2	9,360.1	56,779.3
To Date	Birmingham	63,573	49,941	113,514	42.6	33.5	76.1	184,315,827	27,230,306	211,546,133	123,536.1	18,250.9	141,787.0
	Wooster	34,923	18,901	53,824	29.5	15.9	45.4	54,231,534	11,084,492	65,316,026	45,726.4	9,346.1	55,072.5
Apr.	Birmingham	1,135	924	2,059	37.8	30.8	68.6	3,547,574	503,857	4,051,431	118,252.5	16,795.2	135,047.7
	Wooster	708	470	1,178	23.6	15.7	39.3	1,398,992	269,420	1,668,412	46,633.1	8,980.7	55,613.8
May	Birmingham	1,018	924	1,942	32.8	29.8	62.6	3,260,967	503,857	3,764,824	105,192.5	16,253.4	121,445.9
	Wooster	586	489	1,075	18.9	15.8	34.7	1,126,952	380,068	1,507,020	36,353.3	12,260.2	48,613.5
Jun.	Birmingham	1,088	900	1,988	36.3	30.0	66.3	3,485,563	490,770	3,976,333	116,185.4	16,359.0	132,544.4
	Wooster	579	475	1,054	19.3	15.8	35.1	1,046,310	385,700	1,432,010	34,877.0	12,856.7	47,733.7
To Date	Birmingham	65,814	52,689	118,503	41.6	33.3	74.9	194,609,931	28,728,790	223,338,721	122,937.4	18,148.3	141,085.7
	Wooster	36,796	20,335	57,131	28.8	15.9	44.7	57,803,788	12,119,680	69,923,468	45,265.3	9,490.7	54,756.0
Jul.	Birmingham	1,144	932	2,076	36.9	30.1	67.0	3,659,214	508,220	4,167,434	118,039.1	16,394.2	134,433.3
	Wooster	607	480	1,087	19.6	15.5	35.1	1,094,027	389,760	1,483,787	35,291.2	12,572.9	47,864.1
Aug	Birmingham	1,062	957	2,019	34.2	30.9	65.1	3,643,232	521,852	4,165,084	117,523.6	16,833.9	134,357.5
	Wooster	669	470	1,139	21.6	15.2	36.8	1,054,505	381,640	1,436,145	34,016.3	12,311.0	46,327.3
Sep.	Birmingham	1,058	922	1,980	35.3	30.7	66.0	3,729,563	502,767	4,232,330	124,318.8	16,758.9	141,077.7
	Wooster	593	450	1,043	19.8	15.0	34.8	1,024,216	365,400	1,389,616	34,140.5	12,180.0	46,320.5
To Date	Birmingham	69,078	55,500	124,578	41.2	33.1	74.3	205,641,940	30,261,629	235,903,569	122,771.3	18,066.7	140,838.0
	Wooster	38,665	21,735	60,400	28.2	15.9	44.1	60,976,536	13,256,480	74,233,016	44,540.9	9,683.3	54,224.2
Oct.	Birmingham	1,061	957	2,018	34.2	30.9	65.1	3,510,641	521,852	4,032,493	113,246.5	16,833.9	130,080.4
	Wooster	615	491	1,106	19.8	15.8	35.7	1,036,290	398,692	1,434,982	33,428.7	12,861.0	46,289.7
Nov.	Birmingham	1,030	887	1,917	34.3	29.6	63.9	3,539,116	483,671	4,022,787	117,970.5	16,122.4	134,092.9
	Wooster	591	472	1,063	19.7	15.7	35.4	967,019	383,264	1,350,283	32,233.9	12,775.5	45,009.4
Dec.	Birmingham	1,069	937	2,006	34.5	30.2	64.7	3,558,763	510,946	4,069,709	114,798.8	16,482.1	131,280.9
	Wooster	628	496	1,124	20.3	16.0	36.3	925,505	402,752	1,328,257	29855.0	12,992.0	42,847.0
To Date	Birmingham	72,238	58281	130,519	40.9	32.9	73.8	216,250,460	31,778,098	248,028,558	122,382.8	17,984.2	140,367.0
	Woosfer	40,499	23194	63,693	27.7	15.9	43.6	63,905,350	14,441,188	78,346,538	43,740.8	9,884.5	53,625.3

* Birmingham from March 1.1910 ; Wooster from January 1.1911.

Record of Tonnage over Screw Spike Test Track Birmingham, Pa. and Wooster, Ohio.

1915		Number of Trains						Tonnage					
		Per Month			Per Day			Per Month			Per Day		
		Fr't	Pass.	F.&P	Fr't	Pass	F&P.	Freight	Passenger	Frt & Pass.	Freight	Pass.	Frt & Pass
Jan.	Birmingham	1190	937	2127	38 4	30.2	68.6	3,867,799	510,946	4,378,745	124,767.7	16,482.1	141,249.8
	Wooster	622	483	1105	20.1	15.6	35.7	995,511	392,196	1,387,707	32,113.0	12,651.0	44,764.0
Feb	Birmingham	1003	831	1834	35.8	29.7	65.5	3,317,790	453,144	3,770,934	118,492.5	16,183.7	134,676.2
	Wooster	559	437	996	19.9	15.6	35.6	883,663	354,844	1,238,507	31,559.0	12,673.0	44,232.0
Mar	Birmingham	1088	924	2012	35.1	29.8	64.9	3,815,753	503,857	4,319,610	123,088.8	16,253.5	139,342.3
	Wooster	629	482	1111	20.3	15.6	35.8	1,052,953	391,384	1,444,337	33,966.0	12,625.0	46,591.0
* To Date	Birmingham	75,519	60.973	136,492	40.7	32.8	73.5	227,251,802	33,246,045	260,497,847	122,375.8	17,903.1	140,278.9
	Wooster	42,309	24,596	66,905	27.3	15.9	43.2	66,837,477	15,579,612	82,417,089	43,093.2	10,044.9	53,138.1
Apr	Birmingham	1010	911	1921	33.7	30.3	64.0	3,679,517	496,768	4,176,285	122,650.6	16,558.9	139,209.5
	Wooster	592	469	1061	19.7	15.6	35.4	1,026,921	380,828	1,407,749	34,230.0	12,694.0	46,924.0
May	Birmingham	1019	935	1954	32.8	30.2	63.0	3,655,091	509,855	4,164,946	117,906.1	16,447.0	134,353.1
	Wooster	647	486	1133	20.9	15.7	36.6	1,144,074	394,632	1,538,706	36,905.0	12,730.0	49,635.0
Jun.	Birmingham	1050	920	1970	35.0	30.7	65.7	3,660,796	501,676	4,162,472	122,026.5	16,722.5	138,749.1
	Wooster	641	471	1112	21.3	15.7	37.0	1,175,257	382,452	1,557,709	39,175.0	12,748.0	51,923.0
* To Date	Birmingham	78,598	63,739	142,337	40.3	32.7	73.0	238,247,206	34,754,344	273,001,550	122,303 5	17,841.0	140,144.5
	Wooster	44,189	26,022	70,211	26 9	15.8	42.7	70,183,729	16,737,524	86,921,253	42,742.8	10,193.4	52,936.2
Jul	Birmingham	1092	928	2020	35.2	29.9	65.2	3,862,597	506,038	4,368,635	124,599.9	16,323.8	140,923.7
	Wooster	698	490	1188	22.6	15.9	38.4	1,269,674	397,880	1,667,554	40,957.0	12,835.0	53,792.0
Aug	Birmingham	1125	965	2090	36.3	31.1	67.4	4,306,969	526,214	4,833,183	138,934.5	16,974.7	155,909.1
	Wooster	675	488	1163	21.8	15.7	37.5	1,260,239	396,256	1,656,495	40,653.0	12,782.0	53,435.0
Sep	Birmingham	1217	953	2170	40.6	31.8	72.3	4,678,000	519,671	5,197,671	155,933.3	17,322.4	173,255.7
	Wooster	678	476	1154	22.6	15.8	38.5	1,259,125	386,612	1,645,737	41,970.0	12,887.0	54,857.0
* To Date	Birmingham	82,032	66,585	148,617	40.2	32.6	72.8	251,094,772	36,306,267	287,401,039	123,085.7	17,797.2	140,882.9
	Wooster	46,240	27,476	73,716	26.7	15.8	42.5	73,972,767	17,918,272	91,891,039	42,660.2	10,333.5	52,993.7
Oct	Birmingham												
	Wooster												
Nov.	Birmingham												
	Wooster												
Dec.	Birmingham												
	Wooster												
* To Date	Birmingham												
	Wooster												

* Birmingham from March 1, 1910: Wooster from January 1, 1911.

COLLATERAL TESTS AND CONCLUSIONS.

In 1907, when the study of the track structure for the New York Terminal was taken up, tests were made in the Altoona Laboratory to determine the proper area and thickness of a tie-plate for a wheel load of 26,000 lbs. and the tentative conclusion was that a plate 7 inches by 13½ inches by ⅝ inch would be adequate. A track test was then made which confirmed this conclusion, except as regards the heavy freight traffic such as we have on No. 2 track on the Middle Division, particularly with respect to the low rail on curves. In this test only 17 plates 7 inches by 13½ inches by ⅝ inch were found bent as much as ⅛ inch out of about 3,500 plates carefully measured with a steel straight-edge after from one to four years' service, and all the bent plates were under the low rail on curve and on chestnut ties.

(See letters LRZ to SR 12-13-12 and to SCL 5-6-13 and 7-24-13 pp. 90-120.)

June, 1908, twelve tie-plates—four ½ inch thick, four ¾ inch thick and four 1 inch thick—were placed on three new ties and three ties 9 years old in eastward freight track near Pomeroy, Philadelphia Division. Removed July, 1912. The ½ inch plates were bent 1/16 inch; the others were not bent.

In June, 1908, a number of photos were taken of old ties taken from main track on the Philadelphia Division and split to show the position of the spikes. (See pp. 121 and 122.)

In September, 1908, photos were taken of a number of old tie-plates and spikes taken from main track on Pittsburgh Division showing effects of corrosion. (See pp. 123 and 124.)

In 1909 a series of tests was made by Riehle Bros., Philadelphia, to determine the resistance to penetration and extraction of round and square nail spikes of various dimensions and various kinds of points. The results were somewhat irregular, but indicated that the resistance to extraction of different sizes of spikes does not vary as much as would be expected, the average for ⅝ inch square spikes being 11375 lbs.; for ¾ inch, 11276 lbs., and for ⅞ inch, 12196 lbs. (See pp. 125-129.)

In April, 1909, a test was made by trackmen in West Philadelphia Yard to determine proper sizes of holes for screw-spikes. This test indicated that diameter of hole in white oak should equal that of the core of the spike. (See p. 129.)

In March, 1910, the President asked the Committee (1) Whether the test track was not being constructed on too high a standard of excellence to be comparable with other track, and (2) Whether the rigidity of screw-spike track might not cause breakage of rail. The Chairman (Mr. Richards) replied, (1) That the purpose of the Committee was to make and maintain the test track at the same standard as other main line passenger track, and (2) That it was believed that a little elasticity in track is desirable and should be obtained by leaving a small vertical clearance between screw-spike and rail. (See pp. 129-131.)

In 1913 a test was made at Altoona Laboratory to determine the distribution of load on the tie effected by tie-plates of different thicknesses. (See pp. 131-133.)

In September, 1914, further tests were made at Altoona Laboratory to determine the distribution of load over the surface of the tie effected by tie-plates of different thicknesses. (See pp. 134-138.)

In November, 1914, some tests were made in Altoona Laboratory to determine the crushing strength and the girder strength of a white oak cross-tie, which indicated that the former is about 400 lbs. per sq. in. and the latter about 45,000 lbs.

(See letter CDY to WGC 11-11-14 pp. 138-141.)

In October, 1915, supplementary tests were made of the distribution of load by the tie-plate over the surface of the tie and of the crushing strength of chestnut ties after five years' service in track as compared with new wood. The former indicated that little if anything can be gained by increasing the length of a tie-plate to 16 inches unless it is made about 1½ inches thick, which is, of course, prohibitively expensive. The test of chestnut ties 5 years old indicated that a tie-plate 1¾ inches thick would be required to keep the load per square inch within the elastic limit of such ties. (See pp. 142-157.)

Arrangements were made in September, 1914, for a field test to determine the load (including impact and dynamic augment) to which each tie-plate in track is subjected. (See letter JTW to WGC 9-14-14—p. 158.) The tests and locations determined upon were as follows:

Location No. 1, eastward freight track, east end of Tipton tangent, E6, K2, K4 and D16 locomotives with tender at 5 mph. and 70 mph.; L1 locomotive at 45 mph.; L1 locomotive with loaded freight train at 45 mph.; L1 locomotive with H21 car loaded and with flat spot 2½ inches long on one pair of wheels at 45 mph.

Location No. 2, eastward freight track, high rail of 2-degree curve east of Tipton. Same tests as No. 1.

Location No. 3, eastward passenger and freight track, low rail of 6-degree curve east of Tyrone Forge—E6, K2, K4, D16 and L1 locomotives with tender at 5 mph. and L1 locomotive with loaded train at 5 mph.

The first series of tests was made with the 20 recording instruments placed on alternate ties and consequently the results were not reliable. The ties under the instruments being tamped solid and the intermediate ties left loose, the former carried nearly all the load. The instruments were then placed on consecutive ties, but the results indicated that similar conditions still prevailed as the readings were alternately very high and very low.

(See report CDY to JTW 2-24-15 pp. 159-193.)

It was therefore arranged to repeat some of the above tests.

(See letter WGC to JTW 3-10-15 p. 194 and 3-18-15 p. 194.)

The supplementary tests on tangent were made in May, 1915, and showed much better results, the loads on the several ties being within a much narrower range, except at two points in the high speed test—doubtless due to dynamic augment. With the exception of the two points named the maximum load was 26,000 lbs.

(See letter JTW to WGC 5-6-15 and WGC to Com. 5-14-15 pp. 195-199.)

The supplementary tests on 6-degree curve were made in May, 1915, and showed that the ratio between load on tangents and on 6-degree curves is 1.27 to 1.52 or an increase of about 40 per cent. (See letter JTW to WGC 6-2-15 p. 199-203.)

In April, 1915, a field test was made to determine the distribution of the load over several ties in track effected by rail of various weights. This test indicated that about 55 per cent. of a load applied directly over a tie is transmitted by 100-lb. rail to other ties so that a tie-plate in track is called upon to sustain only about 45 per cent. of the load imposed on the rail. This explains the fact, brought out by the test of load on each tie-plate in track, that the actual load on each tie-plate (including dynamic augment and impact at high speed) is less than the maximum static wheel load.

(See report CDY to JTW 4-16-15—pp. 204-215.)

In November, 1915, supplementary tests were made of the distribution of load over several ties in track effected by rail of various weights. (See pp. 216-230.)

In March and April, 1915, field tests were made at West Philadelphia to determine the deformation of a cross-tie under static and dynamic loads. The depression of the tie was about the same under dynamic load as under static load, but in every case except on the highest type of roadbed the depression was much greater at the center of the tie than at the ends, indicating that 8 foot 6 inch ties are too long. (See pp. 231-242.) (See "Track Deformations," published by Railway Age Gazette.)

PROPOSED PROGRAM FOR SUPPLEMENTAL TRACK SERVICE TESTS OF TIE-PLATES AND SCREW-SPIKES.

Following the conclusions reached at the inspection of Experimental Track at Birmingham, February 10, 1914, viz., that all the types of tie-plates, of which trial has been made, have proven unsatisfactory by reason of cutting into the ties more rapidly at the outer end than at the inner end, thereby canting the rail, and, second, that the screw-spike had not succeeded in holding the tie-plate firmly to the tie, it was decided to inaugurate a new series of tests with larger and unsymmetrical tie-plates. In this connection the point was suggested that if the unsymmetrical design of the tie-plate prevents the canting of the rail it may develop that an increase in the area of the bearing surface may not be necessary or sufficiently advantageous to justify its cost, the thought being that if the plate cuts vertically and evenly into the tie, this cutting might not shorten its life unreasonably. (See letter WGC to SCL 9-17-14—pp. 243, 244.)

Plans were prepared for seven new types of tie-plates which were tentatively adopted April 19, 1915, subject to revision as to thickness when the results of the field tests of loads imposed on tie-plates became available. These results being before the Committee at its meeting June 15, 1915 (see p. 25) the question of proper load to assume in designing tie-plates was considered.

In connection with the 70 mph. test of load imposed on each tie-plate, attention was called to the fact that, while at two points about 20 ft. apart, a loading of about 35,000 lbs. (inc. dynamic augment and impact) was reached, none of the other tie-plates carried more than 26.000 lbs. (averaging the six runs, the speed being virtually the same on all runs). It was unanimously decided to use a load factor of 26,000 lbs. in designing tie-plates for use in tangent track and under the outer rail on curves, and 36,000 lbs. for tie-plates to be used under the inner rail on sharp curves under heavy traffic. After reading a statement of the fiber stress at elastic limits of various woods as determined by United States Government tests (see p. 199) it was decided to adopt a loading factor of 400 lbs. per square inch for hardwoods and 300 lbs. for softwoods.

As the load per square inch (including dynamic augment and impact), using the factor of 26.000 lbs. agreed upon for tangent track and the outer rail of curves, would be 265 lbs. for a 7 inch by 14 inches and 232 lbs. for a 7 inch by 16 inches tie-plate, and as, even with the factor of 36,000 lbs. adopted for inner rail of sharp curves under heavy traffic (where softwood ties would not be used) these loads would be only 367 lbs. and 321 lbs. respectively, it was considered that the dimensions previously agreed upon, viz., 7 inch by 14 inches and 7 inch by 16 inches were sufficiently liberal.

It was agreed that the thickness of the plates should be such that the adopted loadings of 26,000 lbs. and 36,000 lbs. would not induce a greater fiber stress than 30,000 lbs. per square inch (that being the average elastic limit of tie-plate steel).

It was also decided to lay a stretch of track with the new P. R. R. standard 7 inches by 12 inches by ¾ inch tie-plates for comparison (the load per square inch on the latter being 310 lbs. with the 26,000 factor and 429 lbs. with the 36,000 lbs. factor). It was also decided to lay one-half of the tie-plates of each kind on white oak ties and one-half on long-leaf yellow pine ties.

In conformity with the above and previous decisions of the Committee, the program for the proposed tests is as follows:

Type	*Material*	*Dimensions*	*Spikes*	*Camber*	*Tie Plates*	*Plan*
8 a 1	Wrought steel	7x14"x1" and ¾"	4 nail	None	20	62078
8 a 2	"	7x14"x1" " ¾"	4 screw	"	20	62078
8 a 3	"	7x14"x13/16" " 9/16	4 nail	"	20	62078
8 a 4	"	7x14"x13/16" " 9/16"	4 screw	"	20	62078
8 b 1	"	7x14"x1" " ¾"	4 nail	"	20	62078
8 b 2	"	7x14"x1" " ¾"	4 screw	"	20	62078
8 b 3	"	7x14"x13/16" " 9/16"	4 nail	"	20	62078
8 b 4	"	7x14"x13/16" " 9/16"	4 screw	"	20	62078
9 a 1	Mall. Cast-Iron	7x14"x2"	4 nail	⅛"	20	16476-4
9 a 2	"	7x14"x2"	4 screw	"	20	16476-1 & 3
9 b 1	"	7x14"x2"	4 nail	"	20	16476-4
9 b 2	"	7x14"x2"	4 screw	"	20	16476-1 & 3
10 a 1	"	7x14"x2"	4 nail	None	20	16476-4
10 a 2	"	7x14"x2"	4 screw	"	20	16476-1 & 3
10 b 1	"	7x14"x2"	4 nail	"	20	16476-4
10 b 2	"	7x14"x2"	4 screw	"	20	16476-1 & 3
11 a 1	"	7x16"x2"	4 nail	⅛"	20	16476-5
11 a 2	"	7x16"x2"	4 screw	"	20	16476-2
11 b 1	"	7x16"x2"	4 nail	"	20	16476-5
11 b 2	"	7x16"x2"	4 screw	"	20	16476-2
12 a 1	"	7x16"x2"	4 nail	None	20	16476-5
12 a 2	"	7x16"x2"	4 screw	"	20	16476-2
12 b 1	"	7x16"x2"	4 nail	"	20	16476-5
12 b 2	"	7x16"x2"	4 screw	"	20	16476-2
13 a 1	Wrought steel	7x14"x⅞"	4 nail	"	20	62079
13 a 2	"	7x14"x⅞"	4 screw	"	20	62079
13 a 3	"	7x14"x11/16"	4 nail	"	20	62079
13 a 4	"	7x14"x11/16"	4 screw	"	20	62079
13 b 1	"	7x14"x⅞"	4 nail	"	20	62079
13 b 2	"	7x14"x⅞"	4 screw	"	20	62079
13 b 3	"	7x14"x11/16"	4 nail	"	20	62079
13 b 4	"	7x14"x11/16"	4 screw	"	20	62079
14 a 1	"	7x16"x1"	4 nail	"	20	62080
14 a 2	"	7x16"x1"	4 screw	"	20	62080
14 a 3	"	7x16"x⅞"	4 nail	"	20	62080
14 a 4	"	7x16"x⅞"	4 screw	"	20	62080
14 b 1	"	7x16"x1"	4 nail	"	20	62080
14 b 2	"	7x16"x1"	4 screw	"	20	62080
14 b 3	"	7x16"x⅞"	4 nail	"	20	62080
14 b 4	"	7x16"x⅞"	4 screw	"	20	62080
15 a	"	7x12"x¾"	4 nail	"	40	62175
15 b	"	7x12"x¾"	4 nail	"	40	62175

NOTE.—Thickness for load of 36,000 lbs. indicated by sub-nos. 1 and 2; thickness for load of 26,000 lbs. indicated by sub-nos. 3 and 4;

nail spikes indicated by sub-nos. 1 and 3; screw-spikes indicated by sub-nos. 2 and 4; white oak ties indicated by a; yellow pine ties indicated by b.

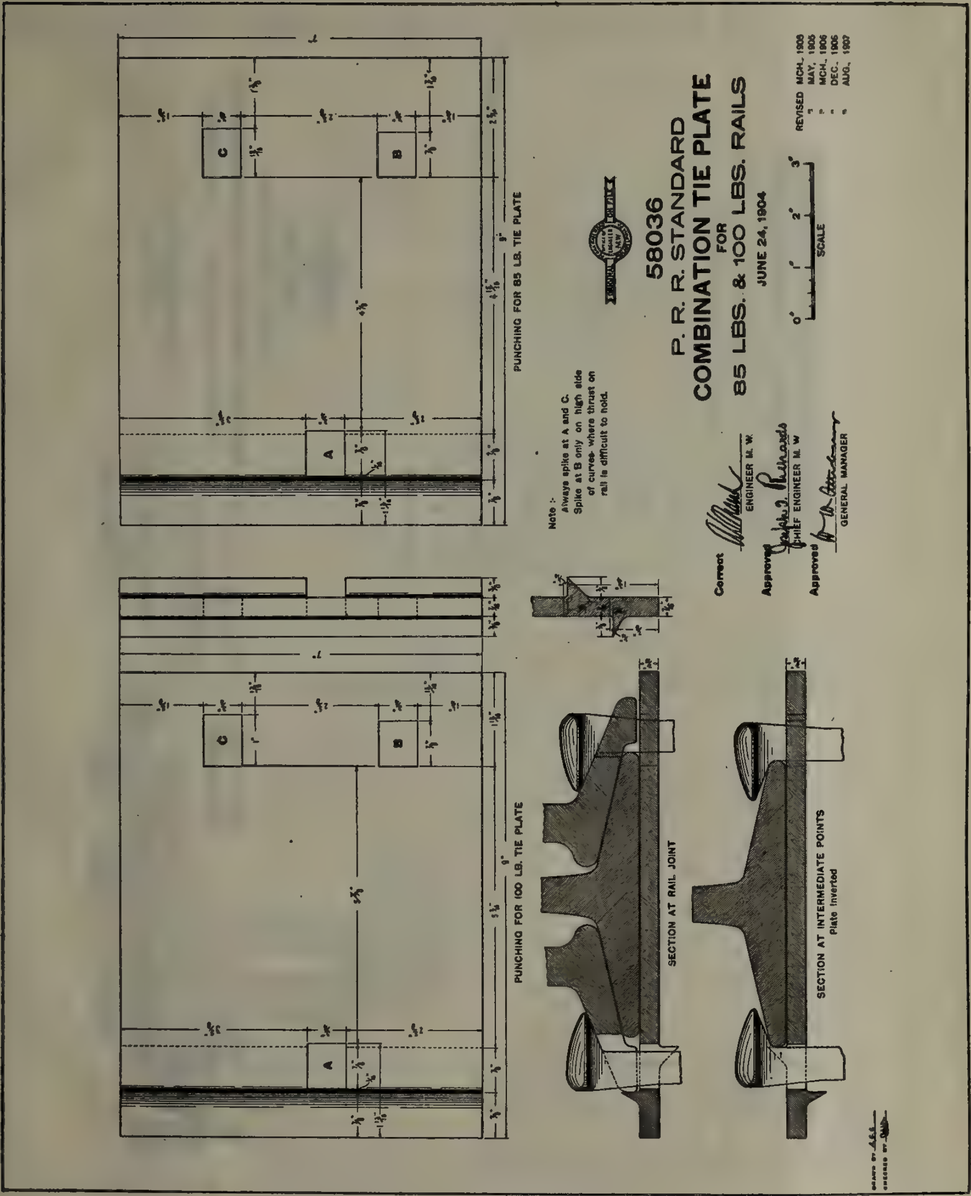
(For plans of proposed tests see inserts, pp. 246, 247.)

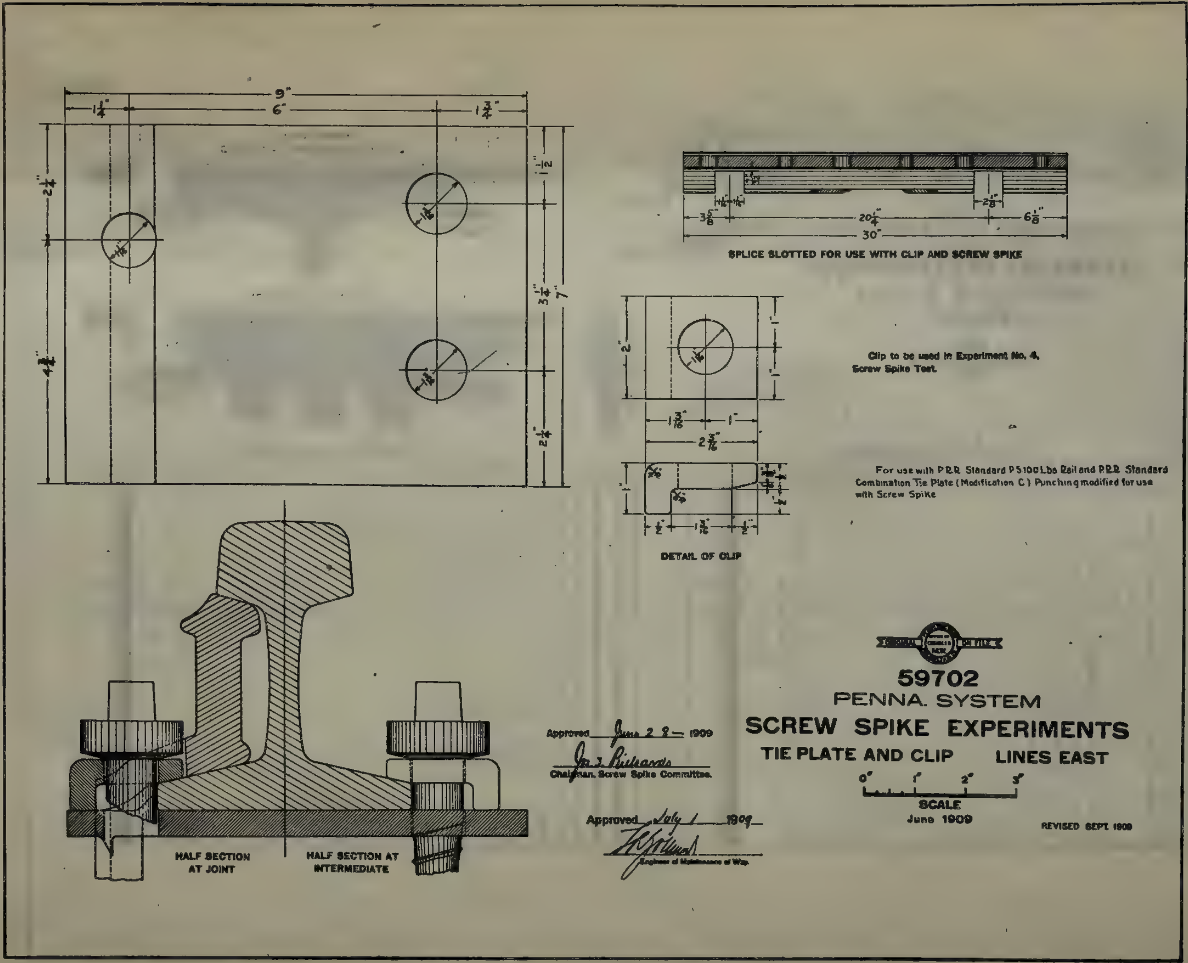
At the meeting of April 19, 1915, it was decided to make a trial of the double tie with "T" tie-plates at joints as recommended by G. Lindenthal in his report upon steel rails. (For plan see p. 247.)

In May, 1915, two hundred wrought steel tie-plates 7 inches by 16 inches by 1½ inches were placed in the eastward passenger and freight track on a 5 degree 45 minute curve east of Birmingham, 100 being secured with screw-spikes and 100 with nail spikes. (See pp. 248-250 for plans and statement of cost.) These tie-plates have not been in service long enough to form any positive conclusions, but it is noticed that although the cutting of the ties is very slight, it is all at the outer end of the plate, notwithstanding the fact that the outer end is 2 inches farther from the rail than the inner end, which may indicate that the remedy for unsymmetrical penetration of tie-plates into ties lies in inclination of the rail rather than in unsymmetrical design of tie-plate.

In May, 1914, Mr. Shand brought up the question of vertical clearance between spike and rail and was informed that such clearance had always been advocated by the chairman of the Committee, but that some of the members had not been in accord with this view.

(See pp. 251, 252.)


58036
P. R. R. STANDARD
COMBINATION TIE PLATE
FOR
85 LBS. & 100 LBS. RAILS
JUNE 24, 1904
SCALE
0" 1" 2" 3"
REVISED MCH., 1905
" MAY, 1906
" MCH., 1906
" DEC., 1906
" AUG., 1907
Note :-
Always spike at A and C.
Spike at B only on high side of curves where thrust on rail is difficult to hold.
Correct
ENGINEER M. W.
Approved
Joseph T. Richards
CHIEF ENGINEER M. W.
Approved
GENERAL MANAGER
PUNCHING FOR 85 LB. TIE PLATE
PUNCHING FOR 100 LB. TIE PLATE
SECTION AT RAIL JOINT
SECTION AT INTERMEDIATE POINTS
Plate Inverted
A
B
C
9"
7"
DRAWN BY
CHECKED BY



SPLICE SLOTTED FOR USE WITH CLIP AND SCREW SPIKE

DETAIL OF CLIP

Clip to be used in Experiment No. 4.
Screw Spike Test.

For use with P.R.R. Standard P.S.100 Lbs Rail and P.R.R. Standard Combination Tie Plate (Modification C) Punching modified for use with Screw Spike

59702
PENNA. SYSTEM
SCREW SPIKE EXPERIMENTS
TIE PLATE AND CLIP LINES EAST
SCALE
June 1909

REVISED SEPT. 1909

Approved June 28 — 1909
Jas. T. Richards
Chairman, Screw Spike Committee.

Approved July 1 1909
Engineer of Maintenance of Way.

LF

XPE

XPE

4b
TOTAL COSTS
432.74
33.55
200.75
39.60
126.50
13.20
132.00
978.34
250.80
143.10
206.70
12.02
85.08
697.70
1676.04
16.56
8743.68
3.04

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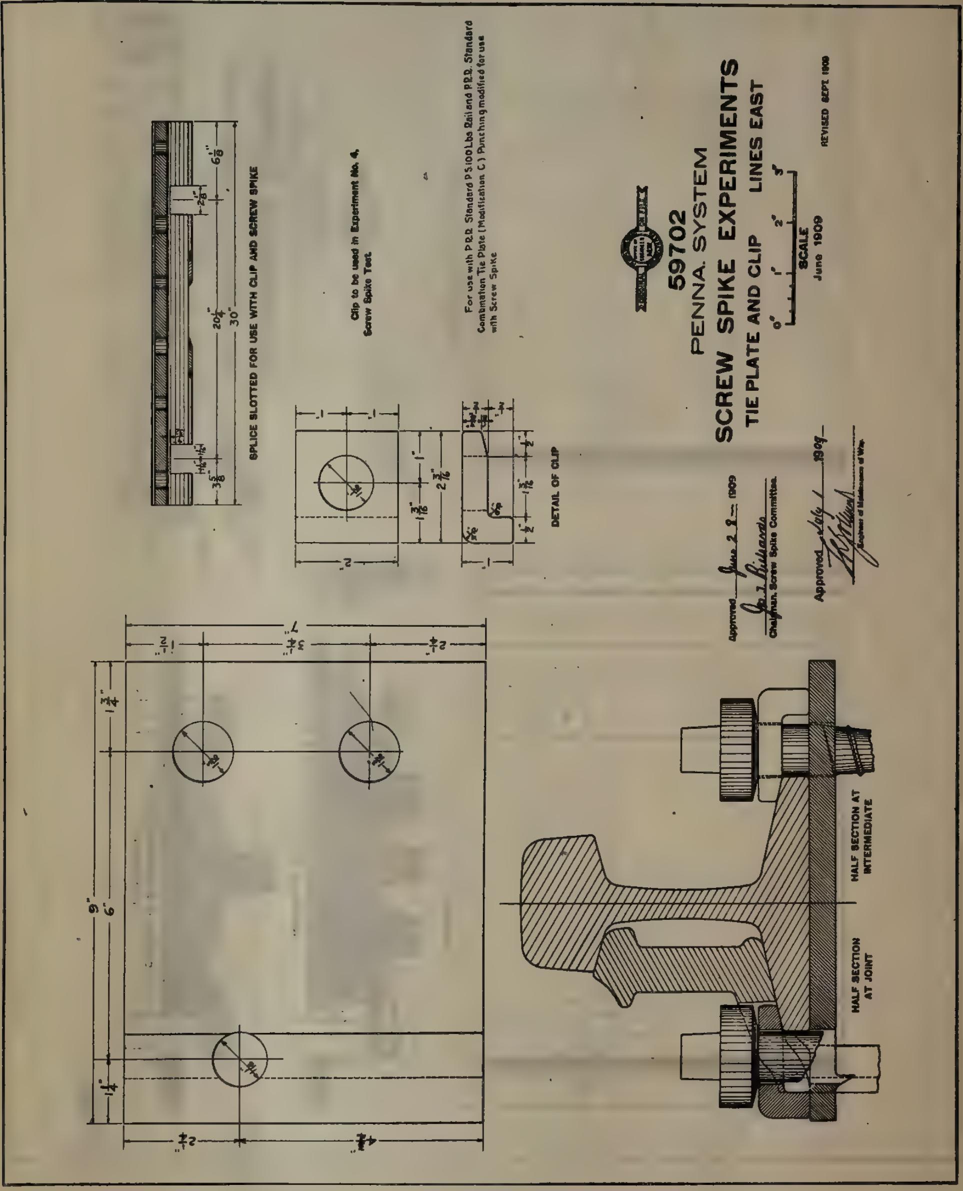
SPLICE SLOTTED FOR USE WITH CLIP AND SCREW SPIKE
30"
20¼"
6⅝"
3⅝"
Clip to be used in Experiment No. 4, Screw Spike Test.
For use with P.R.R. Standard P.S. 100 Lbs. Rail and P.R.R. Standard Combination Tie Plate (Modification C) Punching modified for use with Screw Spike
DETAIL OF CLIP
2"
1"
1$\frac{3}{16}$"
2$\frac{3}{16}$"
½"
9"
6"
7"
1½"
3¼"
2¼"
1¾"
1¼"
2¼"
4¾"
HALF SECTION AT JOINT
HALF SECTION AT INTERMEDIATE
59702
PENNA. SYSTEM
SCREW SPIKE EXPERIMENTS
TIE PLATE AND CLIP
LINES EAST
0' 1' 2' 3'
SCALE
June 1909
REVISED SEPT 1909
Approved June 28 1909
Chairman, Screw Spike Committee.
Approved July 1 1909
Engineer of Maintenance of Way.

PENNSYLVANIA RAILROAD SYSTEM

SCREW SPIKE EXPERIMENTS

RECORD OF COST OF INSTALLATION OF EXPERIMENTAL TRACK AT WOOSTER, O.

TYPE OF TRACK	1a			1b			2			3			4a			4b			6a			6b			7a			7b			TOTALS		
ITEMS	No	TOTAL COSTS	UNIT COSTS	No	TOTAL COSTS	UNIT COSTS	No	TOTAL COSTS	UNIT COSTS	No	TOTAL COSTS	UNIT COSTS	No	TOTAL COSTS	UNIT COSTS	No	TOTAL COSTS	UNIT COSTS	No	TOTAL UNITS	UNIT COSTS	No	TOTAL COSTS	UNIT COSTS	No	TOTAL COSTS	UNIT COSTS	No	TOTAL COSTS	UNIT COSTS	No	TOTAL COSTS	UNIT COSTS
TIES																																	
Original Cost	550	334.35	0.6079	550	432.74	0.7868	550	334.35	0.6079	550	334.35	0.6079	550	334.35	0.6079	550	432.74	0.7868	550	334.35	0.6079	546	429.59	0.7868	550	334.35	0.6079	550	432.74	0.7868	5496	3733.91	0.679
Freight (Delivered to Railroad		49.50	0.09		33.55	0.061		49.50	0.09		49.50	0.09		49.50	0.09		33.55	0.061		49.50	0.09		33.31	0.061		49.50	0.09		33.55	0.061		430.96	0.078
Treatment (Including labor and material Handling at plant and loading for shipment.)		195.25	0.355		200.75	0.365		195.25	0.355		195.25	0.355		195.25	0.355		200.75	0.365		195.25	0.355		199.29	0.365		195.25	0.355		200.75	0.365		1973.04	0.358
Preparation of Fastening (Boring & Handling)		45.21	0.0822		23.50	0.04273		23.65	0.043		82.50	0.15		71.50	0.13		39.60	0.072		69.85	0.127		62.24	0.114		66.00	0.12		29.15	0.053		513.20	0.093
Freight (From Testing plant to Destination)		108.35	0.197		126.50	0.23		108.35	0.197		108.35	0.197		108.35	0.197		126.50	0.23		108.35	0.197		125.58	0.23		108.35	0.197		126.50	0.23		1155.18	0.210
Labor (Unloading and distributing at track		14.52	0.0264		34.78	0.06324		11.00	0.02		12.32	0.0224		13.42	0.0244		13.20	0.024		19.80	0.036		10.70	0.0196		13.20	0.024		18.15	0.033		161.09	0.029
Labor (Placing track exclusive of lining and Surfacing)		77.16	0.1403		51.02	0.09276		89.65	0.163		88.11	0.1602		87.45	0.159		132.00	0.24		99.00	0.18		73.71	0.135		85.25	0.155		58.52	0.1064		841.87	0.153
Totals (Ties in place)	550	824.34	1.4988	550	902.84	1.64153	550	811.75	1.4759	550	870.38	1.5825	550	859.82	1.5633	550	978.34	1.7788	550	876.10	1.5929	546	934.42	1.7114	550	851.90	1.5489	550	899.36	1.6352		8809.25	
RAIL FASTENINGS (Tie plates spikes pads)																																	
Standard 100# P.S. Tie Plates	1100	233.20	0.212	1100	233.20	0.212																									2200	466.40	0.212
Standard shape Special Drilling													1100	250.80	0.228	1100	250.80	0.228													2200	501.60	0.228
Special #1.																																	
Special #2																			1100	945.02	0.8591	1092	938.14	0.8591							2192	1883.16	0.8591
Special (N.Y. Tunnel Design)																									1100	295.13	0.2683	1100	295.13	0.2683	2200	590.26	0.2683
Screw Spikes ¾" diam 6¼" long. ½" diam 4¼" long.										2200	99.00	0.045	3180	143.10	0.045	3180	143.10	0.045	4400	198.00	0.045	4368	196.56	0.045	2200 4400	99.00 84.92	0.045 0.0193	2200 4400	99.00 84.92	0.045 0.0193	21728 8800	977.76 169.84	0.045 0.193
Spikes (Ordinary)	3300	42.08	0.01275	3300	42.08	0.01275	2200	28.05	0.01275																						8800	112.21	0.01275
Clips										2200	126.72	0.0576	3180	206.70	0.065	3180	206.70	0.065	2200	132.00	0.06	2184	131.04	0.06							12944	803.16	0.062
Cow Hair Pads													534	12.28	0.023	544	12.02	0.0221	550	16.23	0.0295	540	9.13	0.0169	550	16.23	0.0295	540	9.13	0.0169	3258	75.02	0.023
Labor Application of Plate and Screws		51.26	0.178		40.08	0.183		20.42	0.184		60.39	0.183		154.68	0.178		85.08	0.178		155.46	0.178		107.49	0.185		130.27	0.177		74.44	0.182		879.57	0.160
Bolts (Square Head).																			2200	134.20	0.061	2184	133.22	0.061							4384	267.42	0.061
Totals - Rail Fastenings		326.54			315.36			48.47			286.11			767.56			697.70			1580.91			1515.58			625.55			562.62			6726.40	
Totals - Ties & Rail Fastenings	550	1150.88	2.0925	550	1218.20	2.215		860.22	1.564	550	1156.49	2.1027	550	1627.38	2.959	550	1676.04	3.04	550	2457.01	4.4071	546	2450.00	4.487	550	1477.45	2.686	550	1461.98	2.658		15535.65	
Unit Costs of above (exclusive of rail, ballast and first lining and surfacing)																																	
Per Ft. of Track		1.113			1.218			0.8517			1.146			1.595			1.656			2.404			2.45			1.441			1.462			1.53	
Per Mile of Track.		5876.64			6431.04			4496.98			6050.88			8421.60			8743.68			12693.12			12936.00			7608.48			7719.36			8078.40	
Per Tie		2.09			2.21			1.56			2.10			2.94			3.04			4.46			4.48			2.68			2.65			2.45	

Note: On account of the special shape of plates for experiment 6 and the small number required, the cost of these is comparatively higher than the cost of the other plates of standard design.

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PENNSYLVANIA RAILROAD SYSTEM

·RECORD·OF·COST·OF·INSTALLATION·OF·EXPERIMENTAL·TRACK·WEST·OF·UNION·FURNACE·

Installed Dec 1909 and Jan. 1910.

TYPE OF TRACK	1a.			1b.			2			3			4a.		
ITEMS.	No.	Total Costs	Unit Costs	No.	Total Costs	Unit Costs	No.	Total Costs	Unit Costs	No.	Total Costs	Unit Costs	No	Total Costs	Unit Costs
TIES															
a. Original Cost	545	306.80	0.563	546	307.40	0.563	555	312.46	0.563	545	306.80	0.563	547	307.96	0.563
b. Freight (Delivered to Railroad)															
c. Treatment (Including labor and material, unloading from cars, handling at plant, and loading for shipment)	545	185.30	0.34	546	185.64	0.34	555	188.70	0.34	545	185.30	0.34	547	185.98	0.34
d. Peperation of tie fastenings - boring, handling.										545	52.52	0.096	547	64.42	0.118
e Freight from treating plant to destination, if any															
f Labor. Unloading and distributing at the track	545	75.68	0.139	546	36.14	0.066	555	49.94	0.09	545	36.14	0.066	547	39.64	0.072
g. Labor.- Placing in track, Exc. of lining and surfacing	545	127.23	0.233	546	175.03	0.321	555	178.90	0.322	545	218.04	0.400	547	262.22	0.479
TOTALS (Ties in Place)		695.05			704.21			730.00			798.89			860.22	
RAIL FASTENINGS (Tieplate, spikes, pads)															
a Tie Plates - P.S. 100lb.	1090	144.53	0.1326	1092	144.80	0.1316									
P.S. 100lb for screw spikes.													1094	143.64	0.1313
N.Y. Design															
Anti-creeping															
Mall. Iron chairs															
b. Screw Spikes 3/4" dia 4½" long										2180	88.07	0.0404	3160	127.66	0.0404
1" dia 6¼" long															
c Spikes (Ordinary Railroad.) 6¼" / 6" lbs	2684	56.43	0.021	2982	62.62	0.021	1682	35.32	0.021						
d. Clips - if used Rolled Steel										2180	130.80	0.06	3160	142.20	0.045
e Cow hair pads - if used													546	12.01	0.022
f. Labor application of plate & screws															
Bolts - 1"x3¼"															
Totals - Rail fastenings		200.96			207.42			35.32			218.87			425.51	
Totals.- Ties and rail fastenings.		896.01			911.63			765.32			1017.76			1285.73	
Unit costs, exclusive of rail, ballast and first lining and surfacing															
Per foot of track		0.897			0.911			0.752			1.018			1.282	
Per mile of track		4735			4810			3972			5377			6771	

TYPE OF TRACK	4b.			6a.			6b.			7a.			7b.			TOTAL		
ITEMS.	No	Total Costs	Unit Costs	No	Total Costs	Unit Costs	No.	Total Costs	Unit Costs	No	Total Costs	Unit Costs	No.	Total Costs	Unit Costs	No.	Total Costs	Unit Costs
TIES																		
a. Original Cost	271 275	152.57 93.50	0.563 0.34	545	306.83	0.563	387 86 74	217.88 48.42 25.16	0.563 0.563 0.34	546	307.40	0.562	320 226	180.16 76.84	0.563 0.34	5468	2950.26	0.558
b. Freight (Delivered to Railroad)																		
c. Treatment (Including labor and material, unloading from cars, handling at plant, and loading for shipment)	546	185.64	0.34	545	185.30	0.34	547	185.98	0.34	546	185.64	0.34	546	185.64	0.34	5468	1859.12	0.34
d. Peperation of tie fastenings - boring, handling.	546	57.20	0.105	545	52.46	0.096	547	52.75	0.096	546	67.15	0.123	546	77.66	0.142	3822	424.16	0.111
e Freight from treating plant to destination, if any																		
f Labor. Unloading and distributing at the track	546	39.84	0.073	545	36.14	0.066	547	36.14	0.066	546	41.57	0.076	546	36.14	0.066	5468	427.87	0.078
g. Labor.- Placing in track, Exc. of lining and surfacing	546	227.46	0.417	545	300.15	0.551	547	310.36	0.567	546	317.47	0.581	546	275.84	0.505	5468	2392.75	0.438
TOTALS (Ties in Place)		752.21			880.88			876.69			919.23			832.28				
RAIL FASTENINGS (Tieplate, spikes, pads)																	8053.	65
a Tie Plates - P.S. 100lb.																2182	289.33	0.1316
P.S. 100lb for screw spikes.	1092	143.38	0.1313													2186	287.02	.1313
N.Y. Design										846	235.32	0.2775	854	236.99	0.2775	1702	472.31	0.2775
Anti-creeping										61	152.50	2.50	58	145.00	2.50	119	297.50	2.50
Mall. Iron chairs				1082	992.19	0.917	1094	1003.20	0.917							2176	1995.39	0.917
b. Screw Spikes 3/4" dia 4½" long	3152	127.34	0.0404	4325	174.85	0.0404	4376	176.79	0.0404	2184	88.23	0.0404	2172	87.75	0.0404	21552	870.69	0.0404
1" dia 6¼" long										4368	87.36	0.020	4344	86.88	0.020	8112	174.24	0.026
c Spikes (Ordinary Railroad.) 6¼" / 6" lbs																7348	154.37	0.021
d. Clips - if used Rolled Steel	3152	141.84	0.045	2164	101.98	0.0499	2188	109.18	0.0499							2180 10664	130.80 501.20	0.06 0.047
e Cow hair pads - if used	546	12.01	0.022	546	12.01	0.022	546	12.01	0.022	546	12.01	0.022	546	12.01	0.022	3276	72.06	0.022
f. Labor application of plate & screws				545	114.33	0.210	547	80.41	0.147	NY 846 AC 61	32.33 29.28	0.038 Per plate 0.48	854 58	44.71 27.84	0.052 0.48	2194	328.90	0.105
Bolts - 1"x3¼"				2164	101.71	0.047	2188	102.84	0.047							4352	204.55	0.047
Totals - Rail fastenings		424.57			1501.07			1484.41			637.01			641.18		57	78	37
Totals.- Ties and rail fastenings.		1180.78			2381.95			2361.12			1556.26			1473.46		13	832 02	
Unit costs, exclusive of rail, ballast and first lining and surfacing																		
Per foot of track		1.18			2.386			2.354			1.554			1.472			1.38	
Per mile of track		6229			12597			12430			8208			7773			7286	

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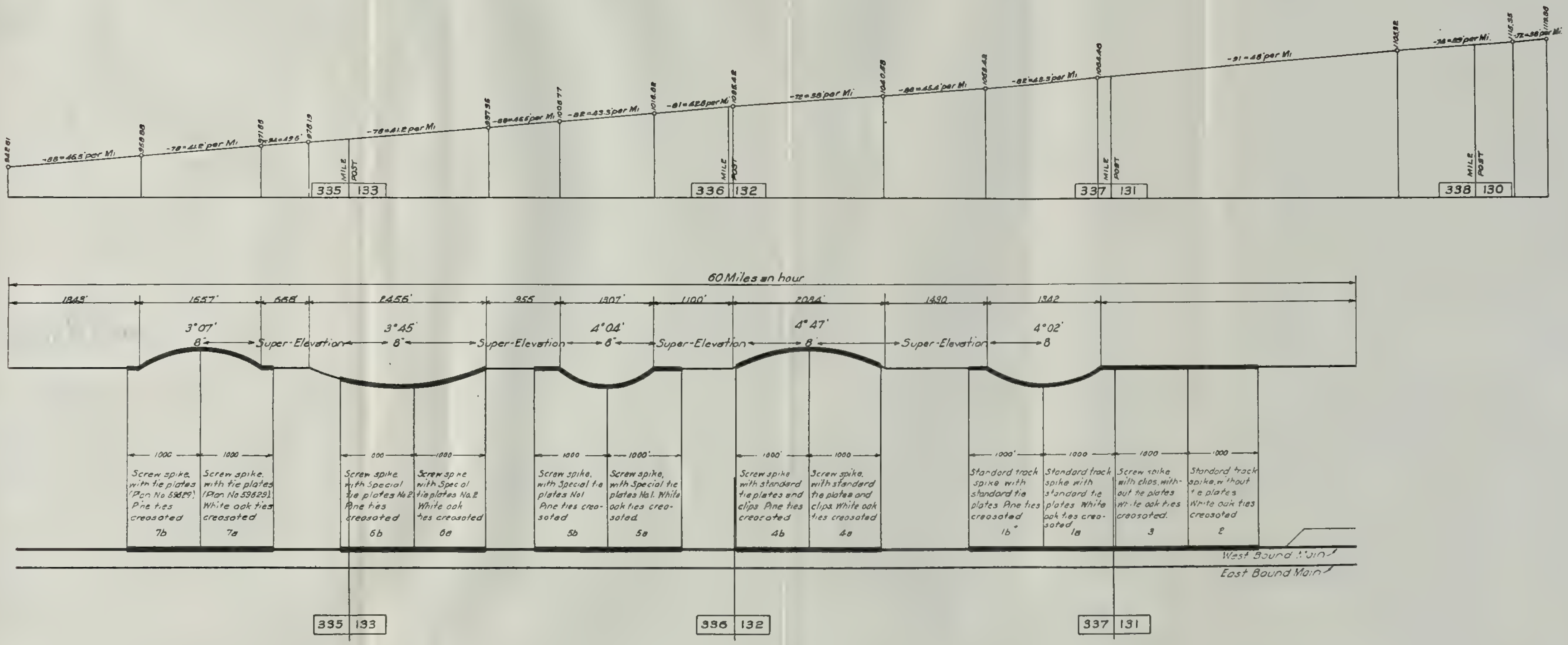
-.88 = 46.5' per Mi
-.78 = 41.2' per Mi
-.94 = 49.6'
-.78 = 41.2 per Mi
-.88 = 46.5' per Mi
1005.77
-.82 = 43.3' per Mi
1016.88
-.81 = 42.8 per Mi
-.72 = 38' per Mi
-.86 = 45.4' per Mi
-.82 = 43.3' per Mi
-.91 = 48' per Mi
-.74 = 39' per Mi
1116.35
-.72 = 38' per Mi
MILE POST
335 133
336 132
337 131
338 130
60 Miles an hour
1848'
1657'
668
2456'
955
1307'
1100'
2084'
1490
1342
3°07'
3°45'
4°04'
4°47'
4°02'
8"
Super-Elevation
1000
Screw spike, with tie plates (Plan No 59829) Pine ties creosoted
7b
Screw spike, with tie plates (Plan No 59829) White oak ties creosoted
7a
Screw spike with Special tie plates No 2 Pine ties creosoted
6b
Screw spike with Special tie plates No 2 White oak ties creosoted
6a
Screw spike, with Special tie plates No1 Pine ties creosoted
5b
Screw spike, with Special tie plates No1. White oak ties creosoted
5a
Screw spike with standard tie plates and clips Pine ties creosoted
4b
Screw spike, with standard tie plates and clips White oak ties creosoted
4a
Standard track spike with standard tie plates Pine ties creosoted
1b
Standard track spike with standard tie plates White oak ties creosoted
1a
Screw spike with clips, without tie plates White oak ties creosoted.
3
Standard track spike, without tie plates White oak ties creosoted
2
West Bound Main
East Bound Main
335 133
336 132
337 131

PENNSYLVANIA RAILROAD SYSTEM

"Screw Spike Experiments"

Diagrams Showing Location on Lines West Main Line P. F. W. & C. Ry., East of Wooster.

May 1909.

Scale: {Hor. 1 inch = 1000 feet.
{Ver. 1 inch = 100 feet.

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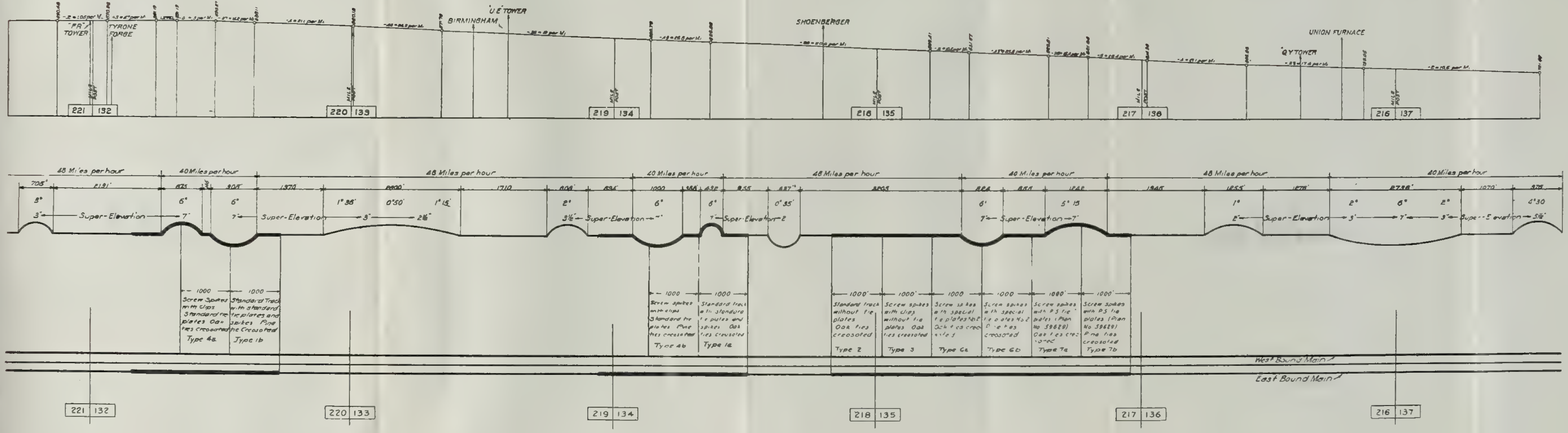
PENNSYLVANIA RAILROAD SYSTEM

"Screw Spike Experiments"

Diagrams Showing Location on Lines East Main Line P. R. R., West of Union Furnace.

May 1909.

Scale: {Hor. 1 inch = 1000 feet.
{Ver. 1 inch = 100 feet.



"FR" TOWER
TYRONE FORGE
"UE" TOWER
BIRMINGHAM
SHOENBERGER
UNION FURNACE
"GY" TOWER
MILE POST
221 132
220 133
219 134
218 135
217 136
216 137
48 Miles per hour
40 Miles per hour
Super-Elevation
1000 Screw Spikes with clips Standard tie plates Oak ties Creosoted Type 4a
1000 Standard Track with standard tie plates and spikes Pine tie Creosoted Type 1b
1000 Screw spikes with clips Standard tie plates Pine ties creosoted Type 4b
1000 Standard track with standard tie plates and spikes Oak ties creosoted Type 1a
1000' Standard track without tie plates Oak ties creosoted Type 2
1000' Screw spikes with clips without tie plates Oak ties creosoted Type 3
1000 Screw spikes with special tie plates No. 1 Oak ties creosoted Type 6a
1000 Screw spikes with special tie plates No 2 Pine ties creosoted Type 6b
1000' Screw spikes with P S tie plates (Plan No 59629) Oak ties creosoted Type 7a
1000' Screw spikes with P S tie plates (Plan No 59629) Pine ties creosoted Type 7b
West Bound Main
East Bound Main

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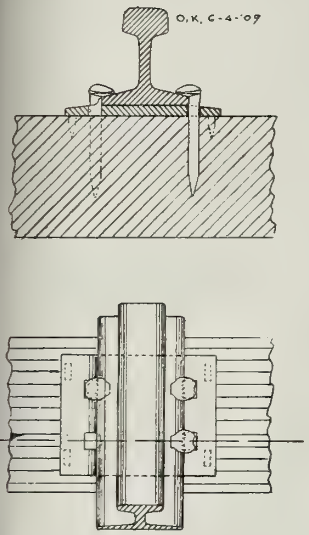
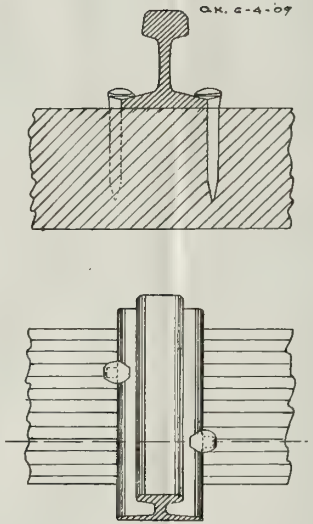
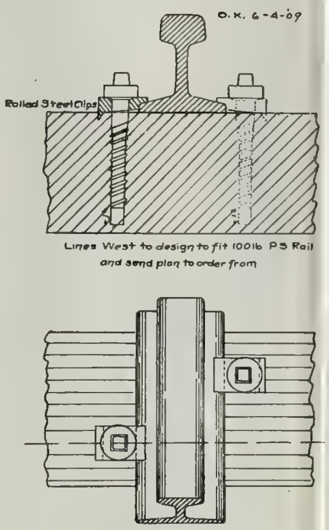


1a
1b

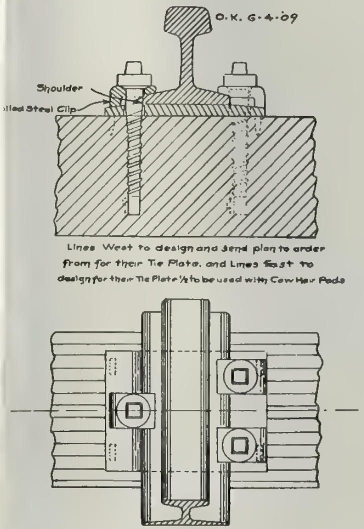


2



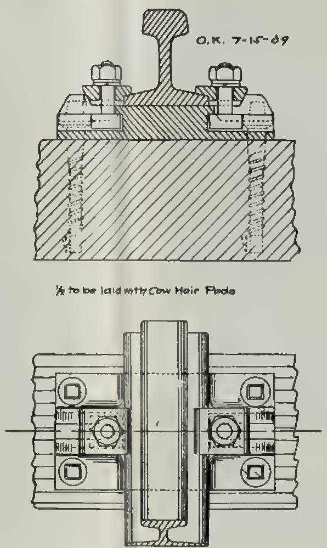
Lines West to design to fit 100lb P.S. Rail and send plan to order from

3



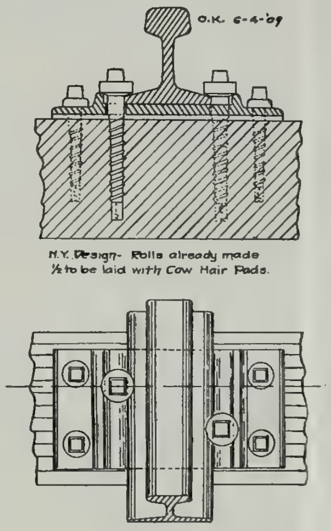
Lines West to design and send plan to order from for their Tie Plate, and Lines East to design for their Tie Plate ½ to be used with Cow Hair Pads

4a
4b



½ to be laid with Cow Hair Pads

6a
6b



N.Y. Design - Rolls already made
½ to be laid with Cow Hair Pads.

7a
7b

DETAIL PLANS					
Experiment	Spikes	Screw Spikes	Clips	Tie Plate	Splices
1 (Lines East)	59472	——	——	58036	59474
1 (Lines West)		——	——		
2 (Lines East	59472	——	——	——	59474
2 (Lines West		——	——	— —	
3	——	59629	59733	—	59702
4 (Lines East	——	59629	59702	59[illegible]2	59702
4 (Lines West	——	59629	59733	59733	59702
6	——	59629	59734	59734	59734
7	——	59629	——	59629	59582

PENNSYLVANIA RAILROAD SYSTEM

"Screw Spike Experiments"

Types of Tie Plates, etc for Experiment
on Lines East & West of Pittsburgh
May 1909. Revised Feb. 1910.
Scale: 3 inches = 1 foot.

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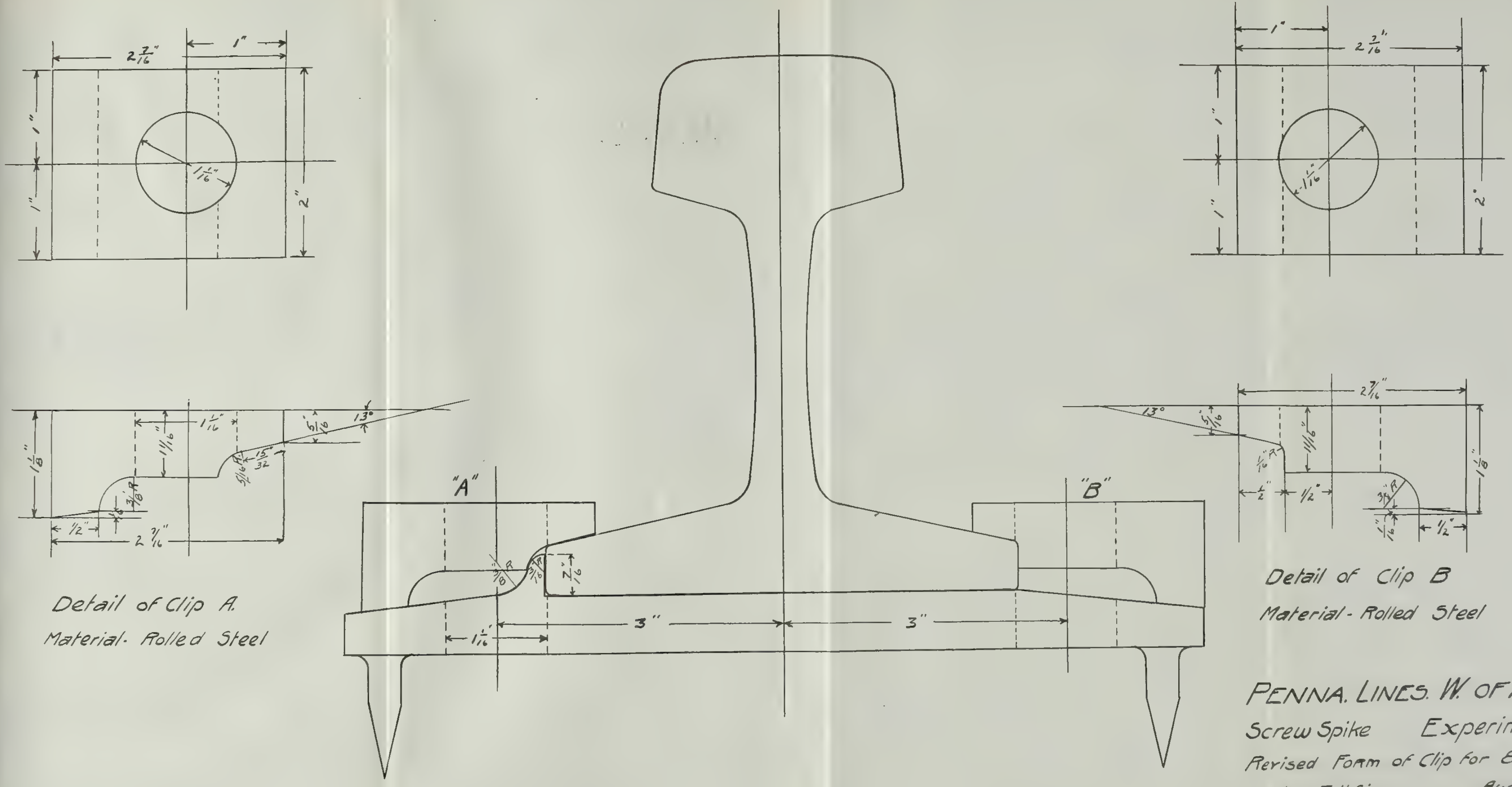

Detail of Clip A.
Material- Rolled Steel

Detail of Clip B
Material - Rolled Steel

PENNA. LINES. W. OF PITTSBURGH.
Screw Spike Experiments.
Revised Form of Clip for Experiment # 4.
Scale = Full Size August 1909
Office of Chief Engineer M. of W.
Nº 14391

Approved ....
Chief Engineer M. of W.

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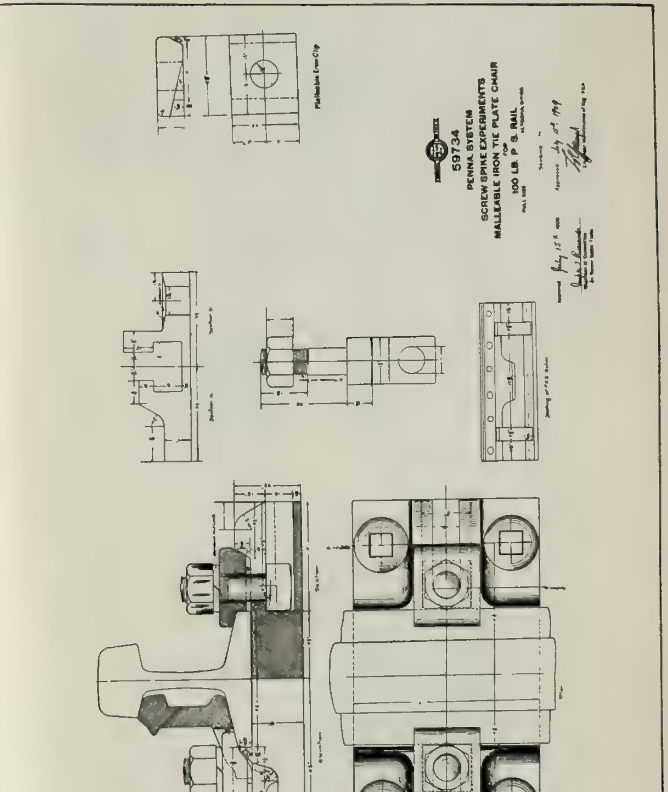
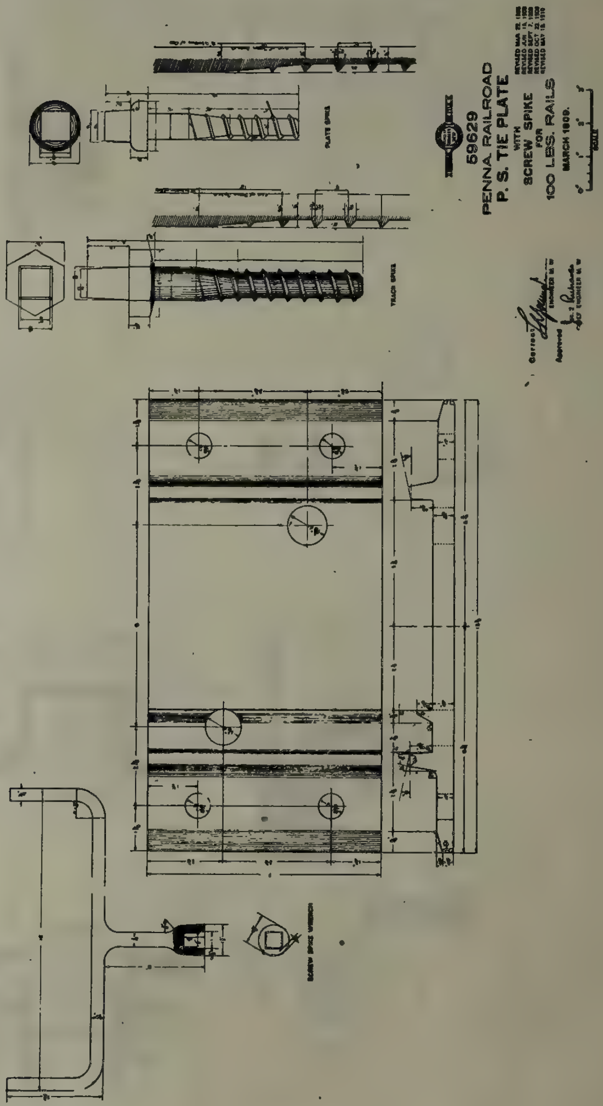
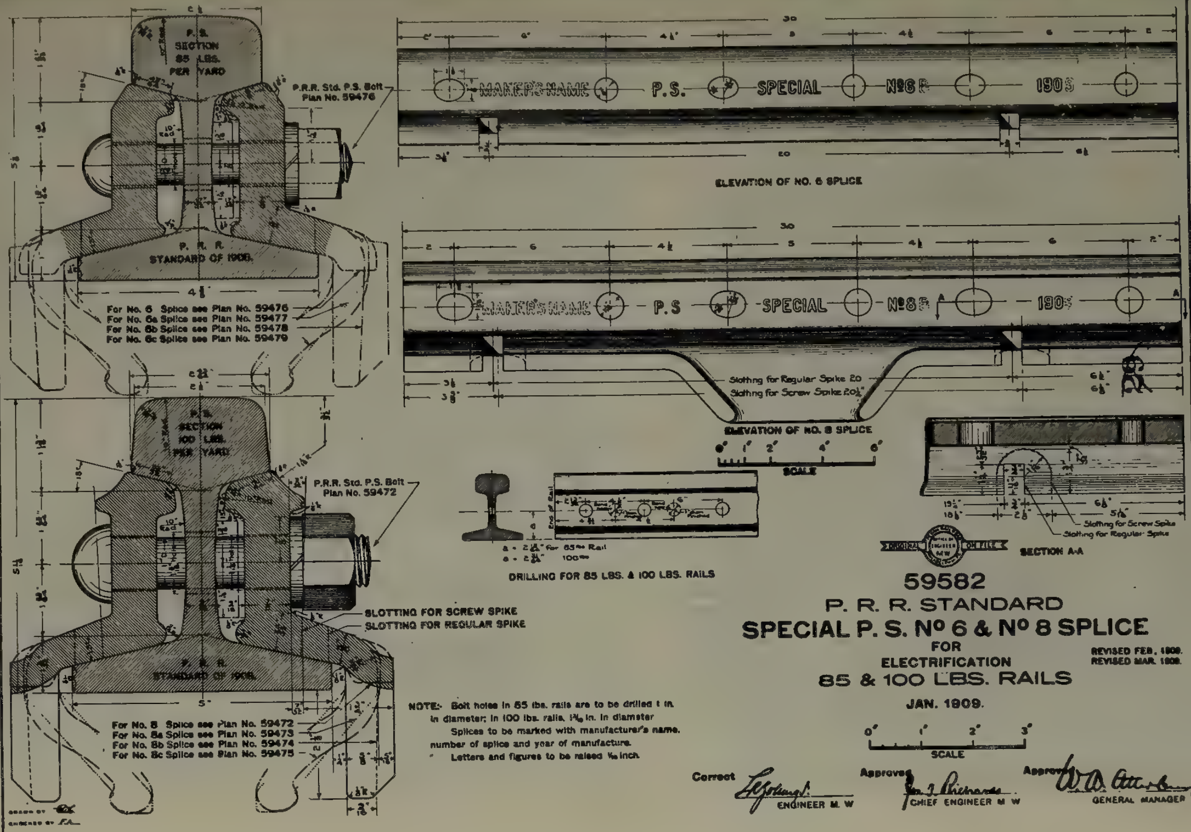

Malleable Iron Clip
59734
PENNA. SYSTEM
SCREW SPIKE EXPERIMENTS
MALLEABLE IRON TIE PLATE CHAIR
FOR
100 LB. P S. RAIL


59629
PENNA RAILROAD
P. S. TIE PLATE
WITH
SCREW SPIKE
FOR
100 LBS. RAILS
MARCH 1909.
SCALE
PLATE SPIKE
TRACK SPIKE
SCREW SPIKE WRENCH
Correct
ENGINEER M. W.
Approved
ENGINEER M. W.


P. S. SECTION 85 LBS. PER YARD
P.R.R. Std. P.S. Bolt Plan No. 59476
P. R. R. STANDARD OF 1908.
For No. 6 Splice see Plan No. 59476
For No. 6a Splice see Plan No. 59477
For No. 6b Splice see Plan No. 59478
For No. 6c Splice see Plan No. 59479
P. S. SECTION 100 LBS. PER YARD
P.R.R. Std. P.S. Bolt Plan No. 59472
SLOTTING FOR SCREW SPIKE
SLOTTING FOR REGULAR SPIKE
P. R. R. STANDARD OF 1908.
For No. 8 Splice see Plan No. 59472
For No. 8a Splice see Plan No. 59473
For No. 8b Splice see Plan No. 59474
For No. 8c Splice see Plan No. 59475
MAKER'S NAME
P.S.
SPECIAL
Nº6 P
1909
ELEVATION OF NO. 6 SPLICE
MAKER'S NAME
P.S
SPECIAL
Nº8 P
1909
Slotting for Regular Spike 20
Slotting for Screw Spike 20½
ELEVATION OF NO. 8 SPLICE
SCALE
DRILLING FOR 85 LBS. & 100 LBS. RAILS
Slotting for Screw Spike
Slotting for Regular Spike
SECTION A-A

NOTE:- Bolt holes in 85 lbs. rails are to be drilled 1 in. in diameter; in 100 lbs. rails, $1\frac{1}{16}$ in. in diameter.

Splices to be marked with manufacturer's name, number of splice and year of manufacture.

Letters and figures to be raised $\frac{1}{16}$ inch.

59582

P. R. R. STANDARD

SPECIAL P. S. Nº 6 & Nº 8 SPLICE

FOR

ELECTRIFICATION

85 & 100 LBS. RAILS

JAN. 1909.

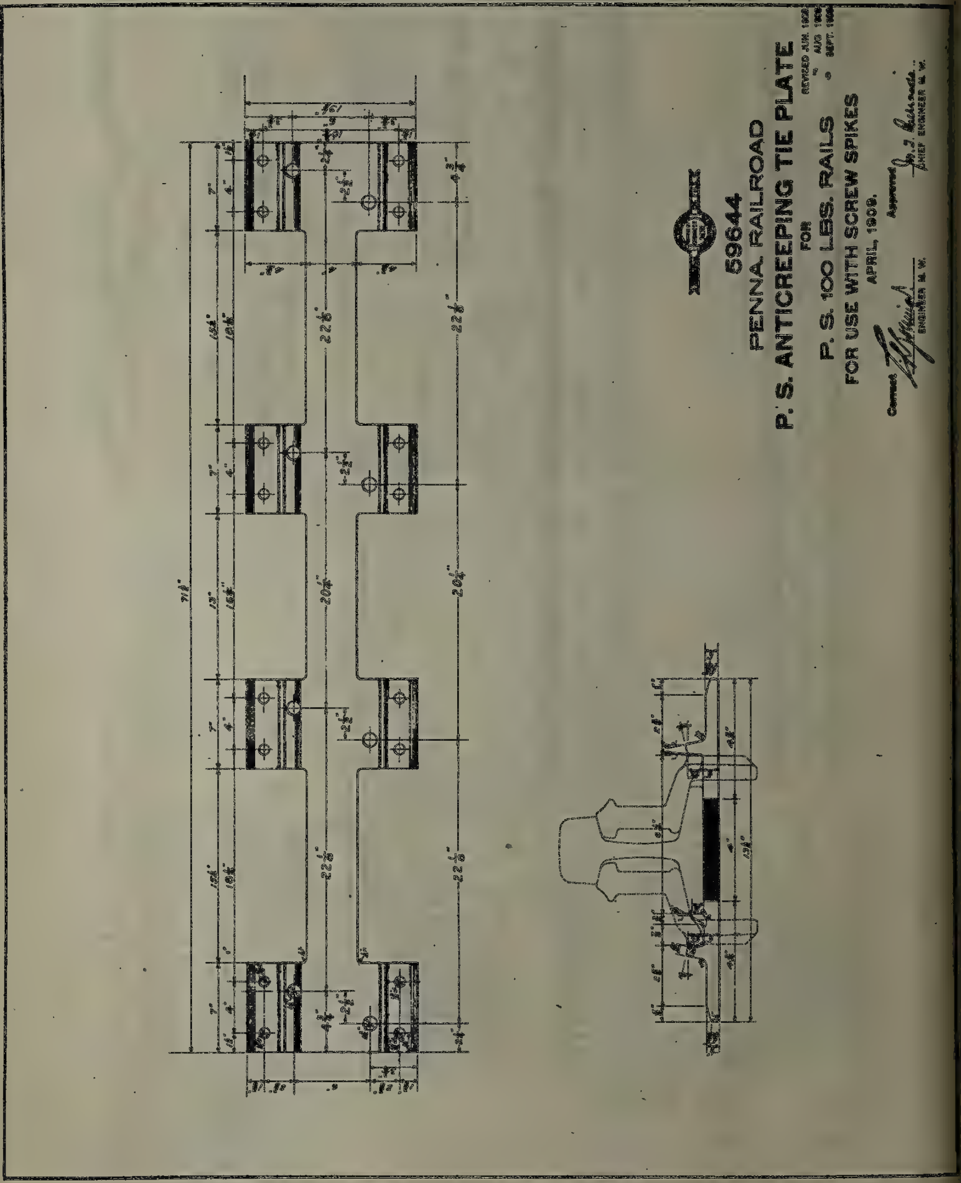
REVISED FEB. 1909.
REVISED MAR. 1909.

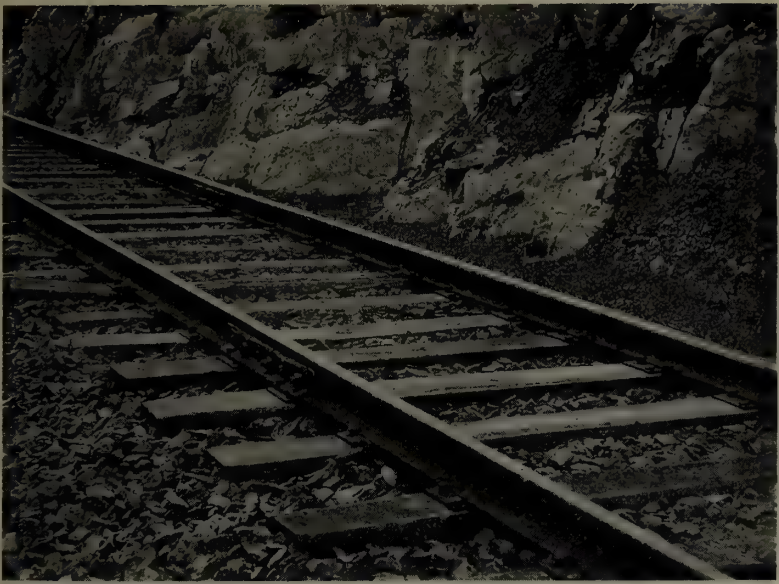
0" 1" 2" 3"
SCALE

Correct ENGINEER M. W

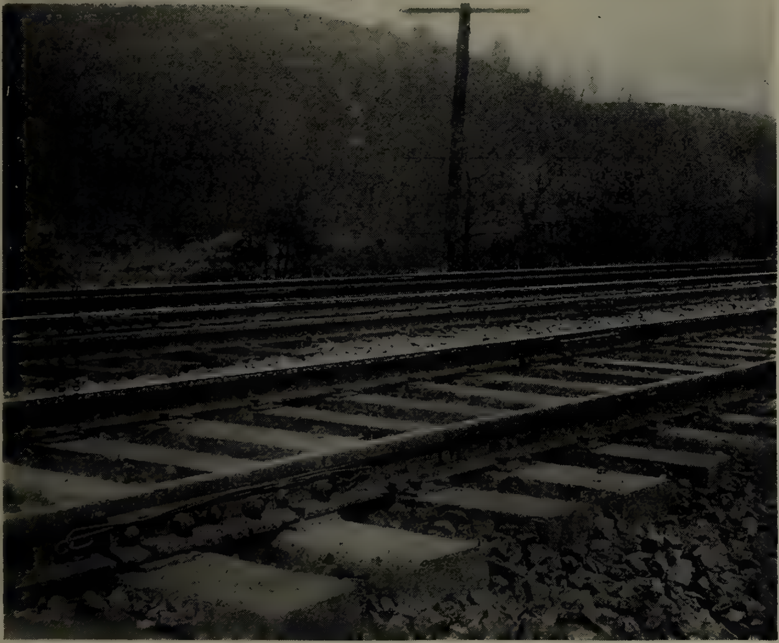
Approved Jno. T. Richards CHIEF ENGINEER M. W

Approved W. W. Atterbury GENERAL MANAGER


59644
PENNA. RAILROAD
P. S. ANTICREEPING TIE PLATE
FOR
P. S. 100 LBS. RAILS
FOR USE WITH SCREW SPIKES
APRIL, 1909.
REVISED JUN. 1909
" AUG 190
" SEPT. 190
Correct
ENGINEER M. W.
Approved
CHIEF ENGINEER M. W.
7"
4"
13"
22 5/8"
20 1/4"
2 1/2"
4 3/4"

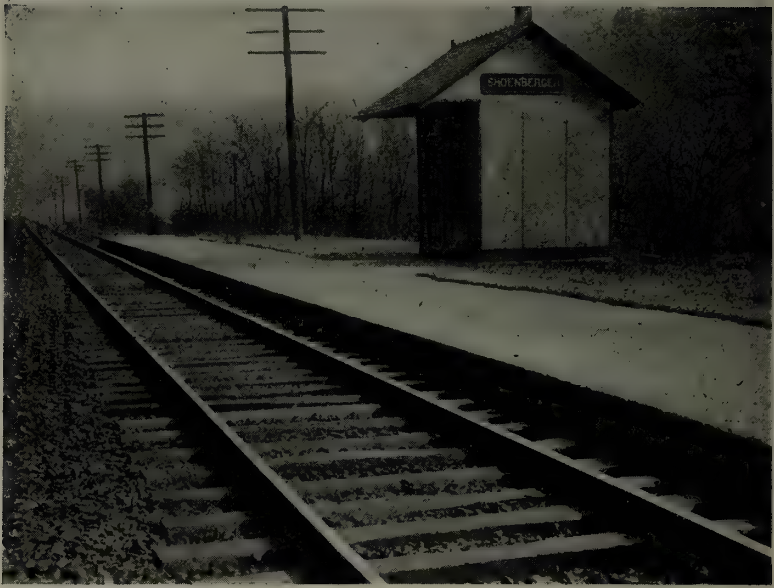


Type 1a.

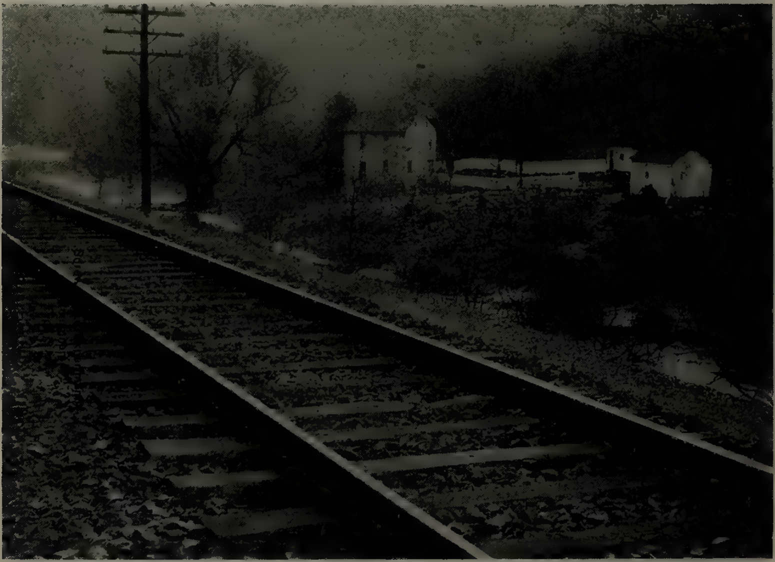


Type 1b.

SCREW-SPIKE EXPERIMENT—BIRMINGHAM; MAY, 1910.



Type 2.

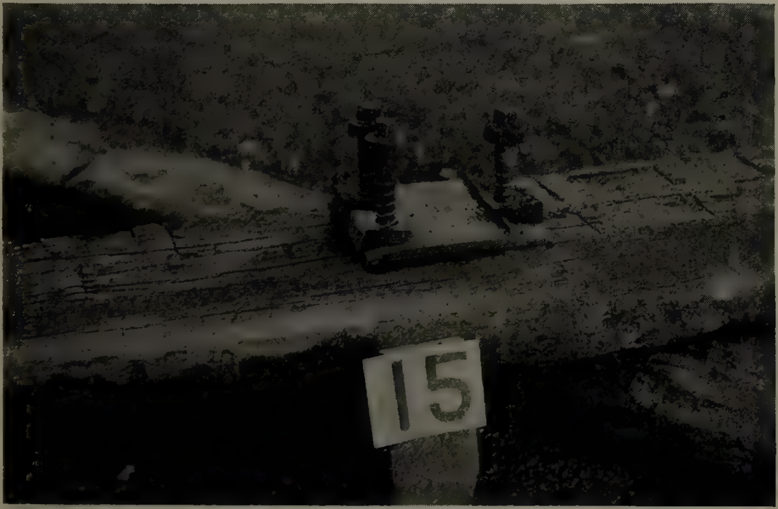


Type 3.

Screw-Spike Experiment—Birmingham; May, 1910.

Type 4a.

Screw-Spike Experiment—Birmingham; May, 1910.



Type 4a.

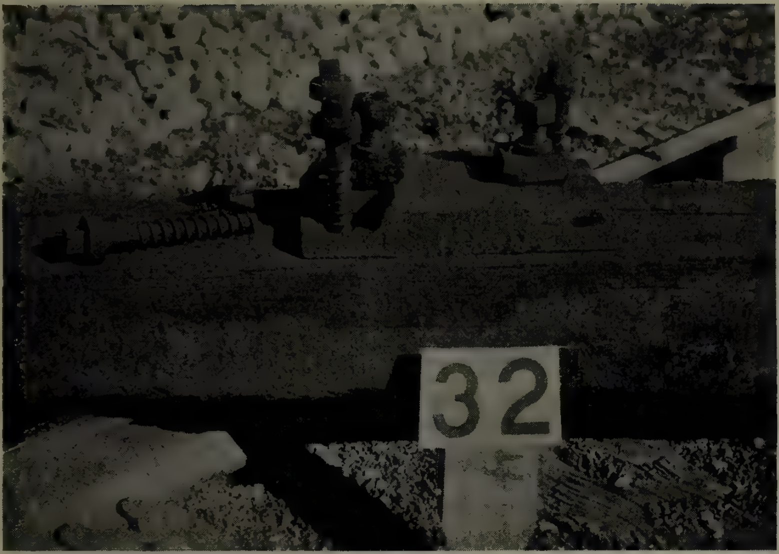
Screw-Spike Experiment—Wooster, Ohio.

Low end of tie to right. Note cow-hair pad projecting from under plate.

Type 4b.

Type 6a.

SCREW-SPIKE EXPERIMENT—BIRMINGHAM; MAY, 1910.



Type 6a.

Screw-Spike Experiment—Wooster, Ohio.

Type 6b.

Screw-Spike Experiment—Birmingham; May, 1910.

Type 7a.

Type 7b.

Screw-Spike Experiment—Birmingham; May, 1910.

Type 7b.

Screw-Spike Experiment—Wooster, Ohio.

INSTRUCTIONS GOVERNING THE INSTALLATION AND INSPECTION OF EXPERIMENTAL TRACK MATERIAL IN CONNECTION WITH SCREW-SPIKE TEST, JUNE 21, 1909. REVISED FEBRUARY 8, 1910.

(1) The Division Engineer of the Division upon which the experiment is to be made (Lines East—Chief Engineer Maintenance of Way Lines West) shall supervise the installation and maintenance of experimental track under the direction of the Committee, and he shall appoint a competent man to take direct charge of the installation and the collection of cost data.

(2) An Inspector is to be sent from the offices of the Chief Engineers Maintenance of Way of the Lines East and West, respectively, to supervise the work during the installation, and check cost data. He shall keep complete records of the cost of installation, and upon completion of each section, forward the record of cost of same on form M. W. Exp.—A, to the Inspector appointed by the Joint Committee. (See paragraph 14.)

(3) The location of the different kinds of experimental track shall be indicated by boards showing the type of experiment and date of installation, the boards to be put in at the ditch line. (See Exhibit "A" pp. 45 and 46.)

(4) The creosoted ties which are to be used, shall be shipped to a designated place, where the holes for the screw-spikes shall be bored, the rail fastenings applied, and nails to designate the species of timber

inserted. If it is known definitely when the ties will be placed in track, the nails with date should also be inserted in this place. The letters "RO" shall be used for red oak, the letters "LP" for loblolly pine, and the letters "YP" for yellow pine. These nails shall be made and placed in accordance with the specifications adopted by the American Railway Engineering and Maintenance of Way Association.

(5) The holes shall be machine bored, using a steel templet to mark their position (suggested design attached—Exhibit "B", p. 47) and suitable appliance shall be used for maintaining the augers absolutely perpendicular to the rail seat. The augers shall have a center point to insure the boring of the holes strictly in accordance with the templet marks, and the holes shall be bored to a depth of one inch in excess of the penetration of the screw-spike, as shown on the plan—the augers being provided with a gage to insure proper depth of hole without variation.

(6) In the oak ties, the diameter of the holes shall be the same as that of the core of the screw-spike, and in the pine ties this diameter shall be one-thirty-second (1/32 inch) of an inch less than the core.

(7) The ties must have a true surface for the tie-plate seat before boring.

(8) Tie-plates which have screw-spikes holding the plate to the tie, independently, of the screw-spike holding the rail, shall be securely fastened to the ties with the outside screw-spikes turned home; the other screw-spikes or clips may be attached or shipped separately, as found most desirable.

(9) No holes are to be bored for the present standard track spikes.

(10) The ties must not be pulled into the track by sticking picks into them.

(11) Screw-spikes must not be driven into the tie, they must be screwed in by use of proper wrench.

(12) A daily report of work done shall be made by the Foreman on form M. W. Exp.—B, approved by the Supervisor, and forwarded to the Inspector appointed by the Division Engineer Lines East—Chief Engineer Maintenance of Way Lines West. (See paragraph 1.)

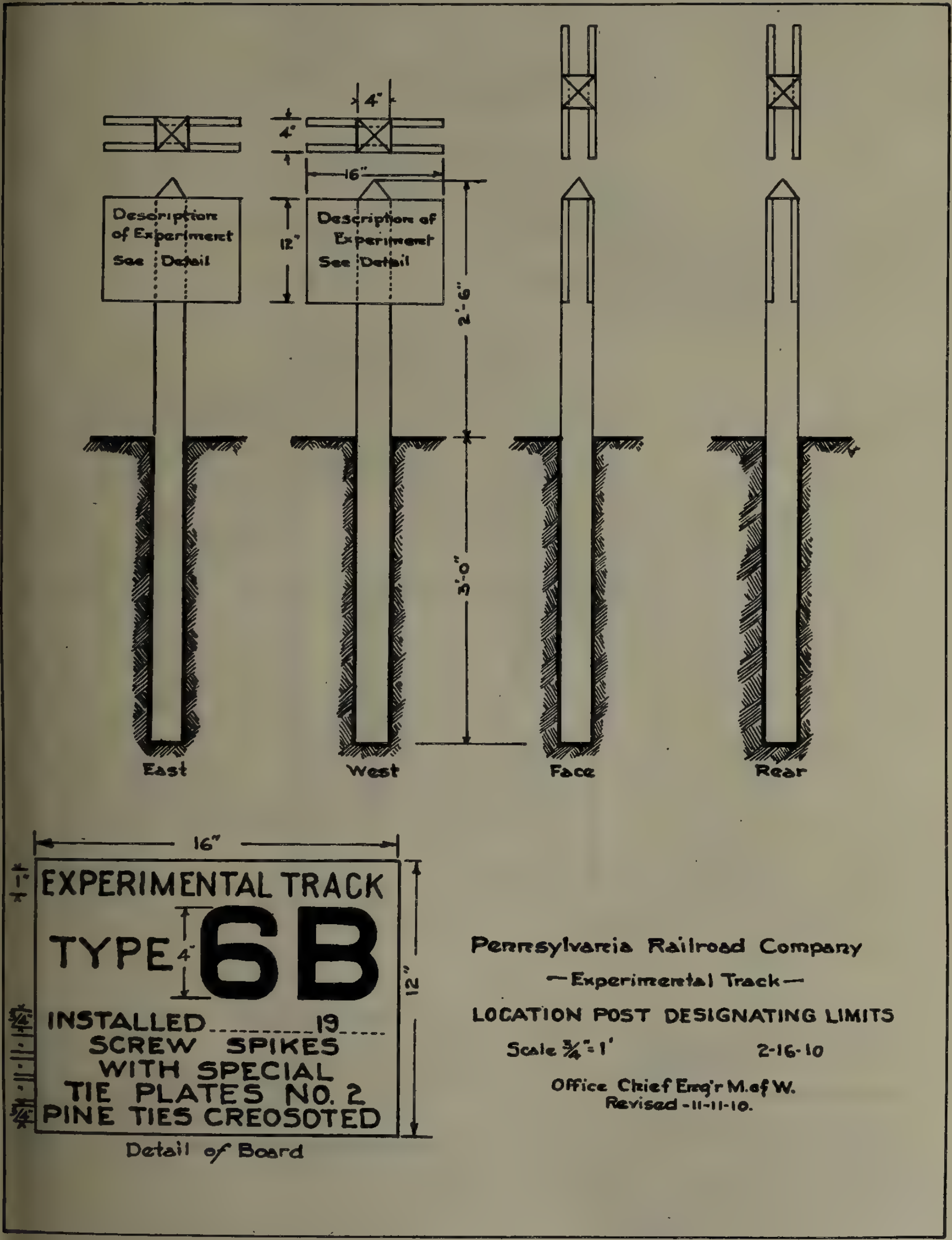
(13) The Inspector appointed by the Division Engineer (Lines East —Chief Engineer Maintenance of Way, Lines West (see paragraph 1) shall make weekly inspections and forward reports of the same on form M. W. Exp.—C, to the Inspector appointed by the Joint Committee (see paragraph 14) transmitting, with his weekly reports, the daily reports of work done, which he receives from the Supervisor.

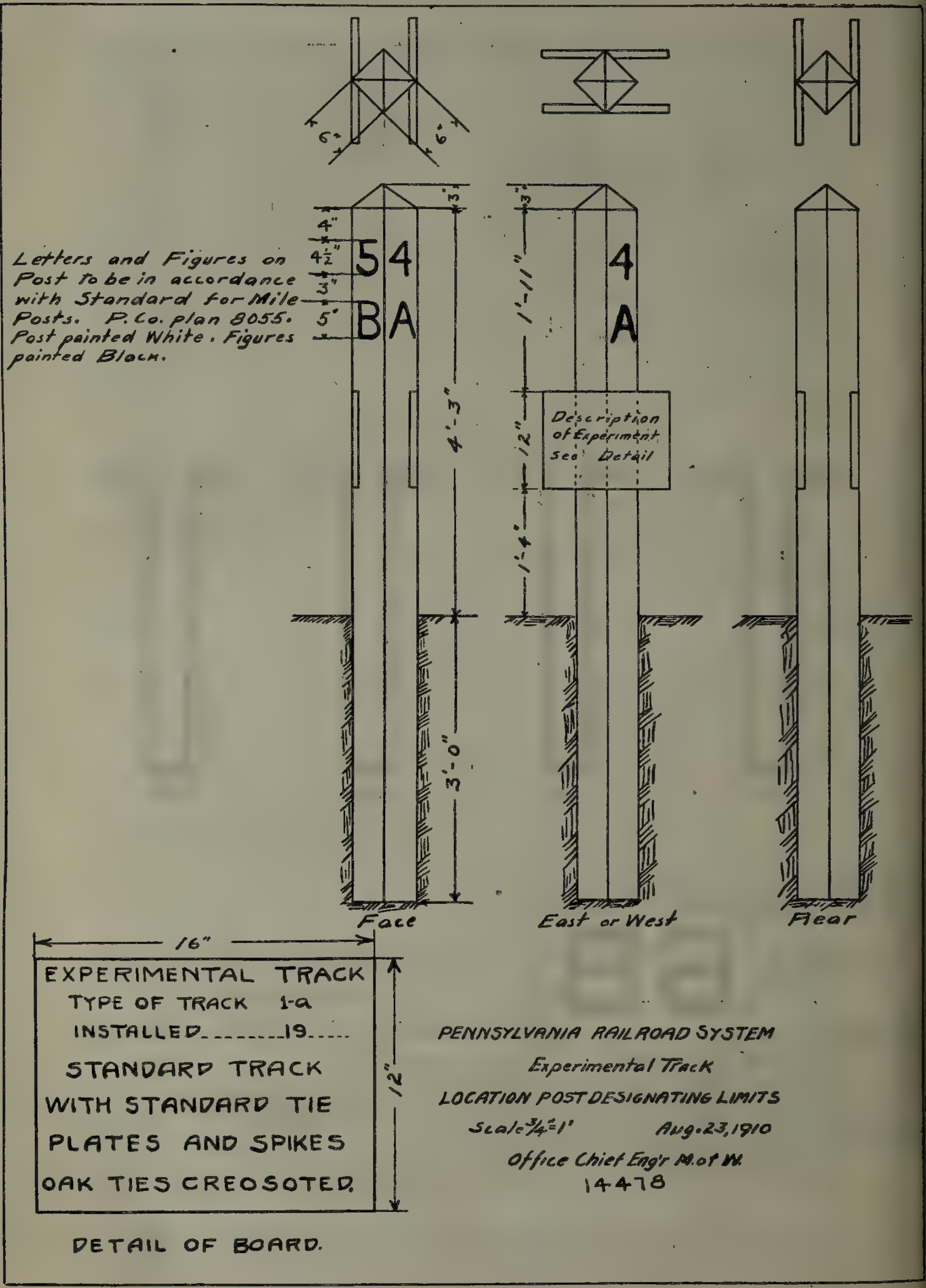
(14) Regular inspections of the experimental track on both the Lines East and West, shall be made once each month by a competent man appointed by the Joint Committee on Screw-Spike Tests. The results of these experiments shall be recorded on form M. W. Exp.—C. The Inspector shall also keep a detailed record of the cost of maintenance of the experimental track on form M. W. Exp.—D. The originals of these reports are to be kept in the files of the Committee, and copies furnished to the Chief Engineers Maintenance of Way of the Lines East and West.

(15) The Joint Committee on Screw-Spike Tests shall make an inspection once every three months during the first year, and once every six months thereafter, and will make a report to the General Managers of the Lines East and West.

(16) After the installation of the above experimental track material, no change must be made in the conditions, except in case of emergency, without written authority from the Joint Committee on Screw-Spike Tests.

(17) Should anything of importance develop between the regular inspections prompt notice of the occurrence must be sent, by the Engineer of the Division, to the Chief Engineer Maintenance of Way.


4"
4"
16"
12"
2'-6"
3'-0"
Description of Experiment See Detail
Description of Experiment See Detail
East
West
Face
Rear
16"
1"
4"
12"
EXPERIMENTAL TRACK
TYPE 6B
INSTALLED__________19____
SCREW SPIKES
WITH SPECIAL
TIE PLATES NO. 2
PINE TIES CREOSOTED
Detail of Board
Pennsylvania Railroad Company
—Experimental Track—
LOCATION POST DESIGNATING LIMITS
Scale ¾"=1'
2-16-10
Office Chief Eng'r M. of W.
Revised -11-11-10.

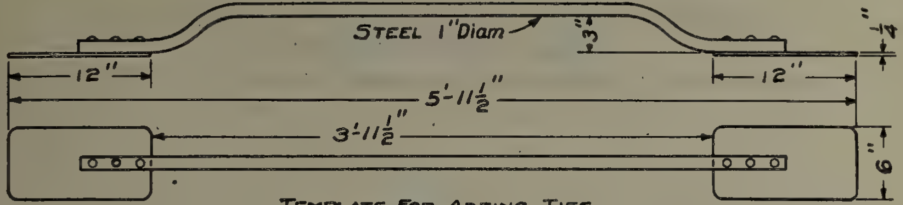


Letters and Figures on Post to be in accordance with Standard for Mile Posts. P. Co. plan 8055. Post painted White. Figures painted Black.

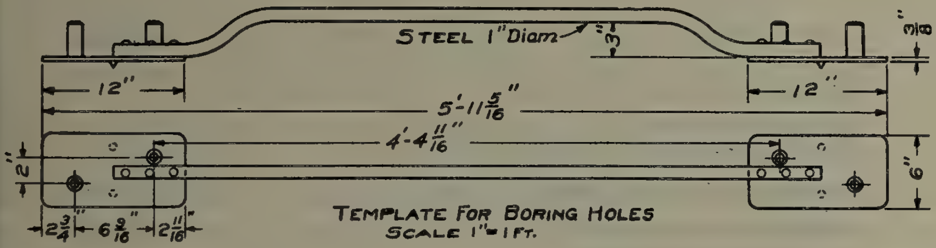
EXPERIMENTAL TRACK
TYPE OF TRACK 1-a
INSTALLED........19.....
STANDARD TRACK
WITH STANDARD TIE
PLATES AND SPIKES
OAK TIES CREOSOTED.

DETAIL OF BOARD.

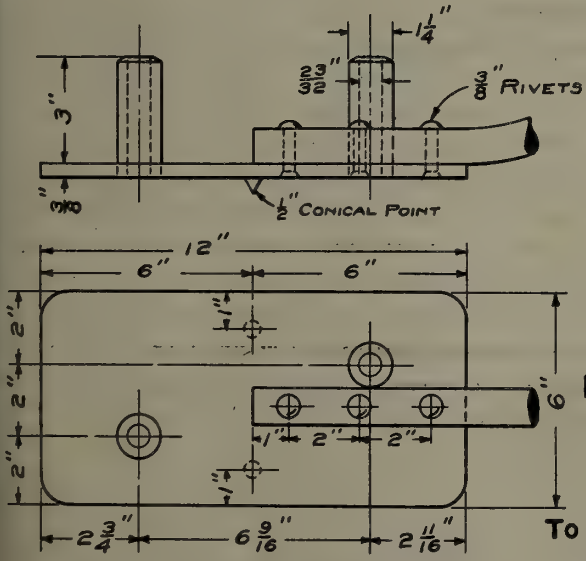
PENNSYLVANIA RAILROAD SYSTEM
Experimental Track
LOCATION POST DESIGNATING LIMITS
Scale ¾"=1' Aug. 23, 1910
Office Chief Eng'r M. of W.
14478



Template for Adzing Ties
Scale 1" = 1 Ft.



Template for Boring Holes
Scale 1" = 1 Ft.



Detail of Template for Boring Holes
Scale 3" = 1 Ft.

Notes:-

11/16" Holes in ties to be bored diameter

This plan to be used for tracks laid with 100 lb. rail only.

For details of tie plates and screw spikes see plans N° 7541 and 7543. Office C.E. M of W.

P. C. C. & St. L. Ry.
PITTSBURGH DIV.
Details of Templates
For Preparing Ties
To be used with Screw Spikes
Office of Engr. M. of W.
Pittsburgh March 1905.
Scale as shown

M. W. Exp.—A.

PENNSYLVANIA RAILROAD SYSTEM

SCREW SPIKE EXPERIMENTS

Record of Cost of Installation of Experimental Track at..

Type of Track..............................length..............feet Installed,...191......

Description {
....
....
....
....
....
}

Sketch {
}

ITEMS	NUMBER	TOTAL COSTS	UNIT COSTS
TIES			
a. Original cost			
b. Freight (Delivered to Railroad)			
c. Treatment {Including labor and material, unloading from cars, handling at plant, and loading for shipment.}			
d. Preparation of tie fastenings—boring, handling			
e. Freight from treating plant to destination, if any			
f. Labor unloading and distributing at the track			
g. Labor placing in track, exclusive of lining and surfacing			
TOTALS (Ties in place)			
RAIL FASTENINGS (Tie plates, spikes and pads)			
a. Tie plates, kind			
b. Screw spikes.......................diam...........................length			
c. Spikes (ordinary railroad)			
d. Clips—If used			
e. Cow hair pads—If used			
f. Labor—application of plate and screws			
TOTALS—RAIL FASTENINGS			
TOTALS—TIES AND RAIL FASTENINGS			

Unit costs of the above (exclusive of rail, ballast and first lining and surfacing):

Per foot of track . . . . $..........................

Per mile of track . . . .

M. W. Exp.—B.

PENNSYLVANIA RAILROAD SYSTEM

Daily Report of Work Done by Trackmen on Experimental Track at ....

Kind of Track .... Date ....

KIND OF WORK DONE	NUMBER OF HOURS	RATE PER HOUR	TOTAL
Surfacing			
Lining			
Gauging			
Tightening Rail Fastenings			
Renewing Rail Fastenings			
Tightening Joint Bolts			
Renewing Joint Bolts			
TOTALS			

Material used replacing worn-out or broken material, No. ....Kind........................

Exclude from this report all labor ditching, policing, and cleaning right of way.

To be made out DAILY and forwarded to the Inspector appointed by the Joint Committee.

When no work is done make a report to that effect.

CORRECT:

....Foreman

....Supervisor

M. W. Exp.—C.

PENNSYLVANIA RAILROAD SYSTEM

Report of Physical Condition of Experimental Track at ....

Date ....

TYPE OF TRACK	LINE	SURFACE	GAUGE	LOOSE SPIKES	WORN SPIKES	BENT SPIKES	BROKEN SPIKES INTERMED. TIE	BROKEN SPIKES JOINT TIES	LOOSE CLIPS	BROKEN CLIPS	SLEWED TIES	TIE CUT BY RAIL	TIE CUT BY PLATES	CONDITION OF TIES
1-a														
1-b														
2														
3														
4-a														
4-b														
6-a														
6-b														
7-a														
7-b														

MARKS—(Line, Surface and Ties)="E" Excellent; "G" Good; "P" Poor; "B" Bad; "M" Medium.

GAUGE—To be measured and recorded;

"Loose", "Worn" and "Bent" Spikes, etc., to be reported by number.

REMARKS:

NOTE: This report is to be made in duplicate and copies furnished to Chief Engineers Maintenance of Way, Lines East and West.

M. W. Exp.—D.

PENNSYLVANIA RAILROAD SYSTEM

Record of Cost of Maintenance of Experimental Track at……………………

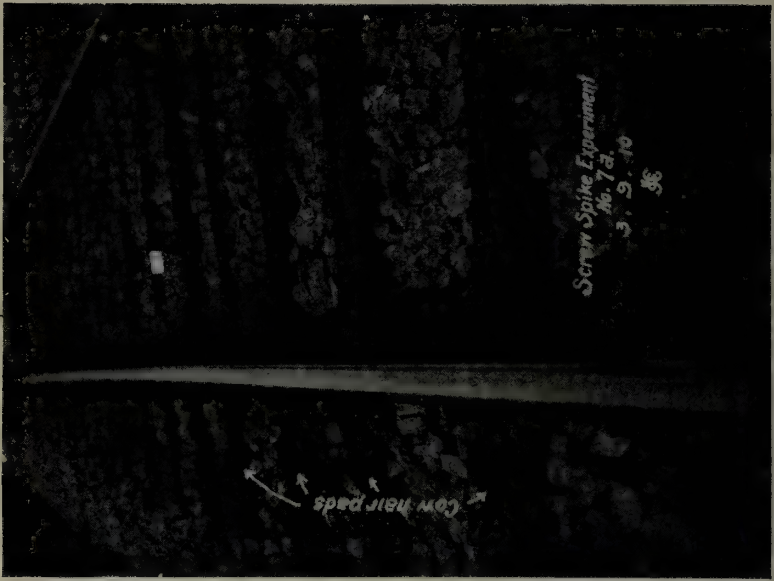
Month of……………………………………

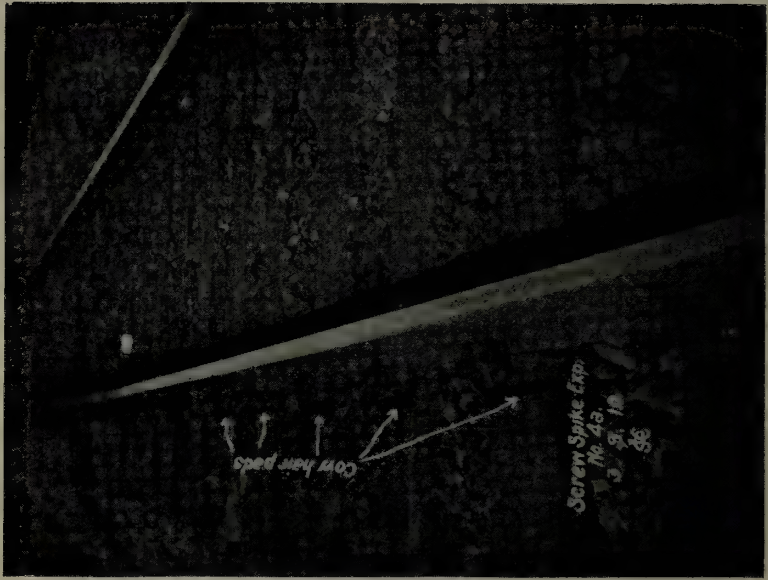
TYPE OF TRACK	SURFACING	LINING	GAUGING	Tightening Rail Fastenings	Renewing Rail Fastenings	Tightening Joint Bolts	Renewing Joint Bolts	TOTAL LABOR	COST OF MATERIAL USED IN RENEWAL	GRAND TOTAL
FOR MONTH										
1-a										
1-b										
2										
3										
4-a										
4-b										
6-a										
6-b										
7-a										
7-b										

TOTAL TO DATE

1-a										
1-b										
2										
3										
4-a										
4-b										
6-a										
6-b										
7-a										
7-b										

NOTE:—This record to be compiled monthly, in duplicate, in office of Chief Engineer Maintenance of Way and copies furnished to Chief Engineers Maintenance of Way, Lines East and West.

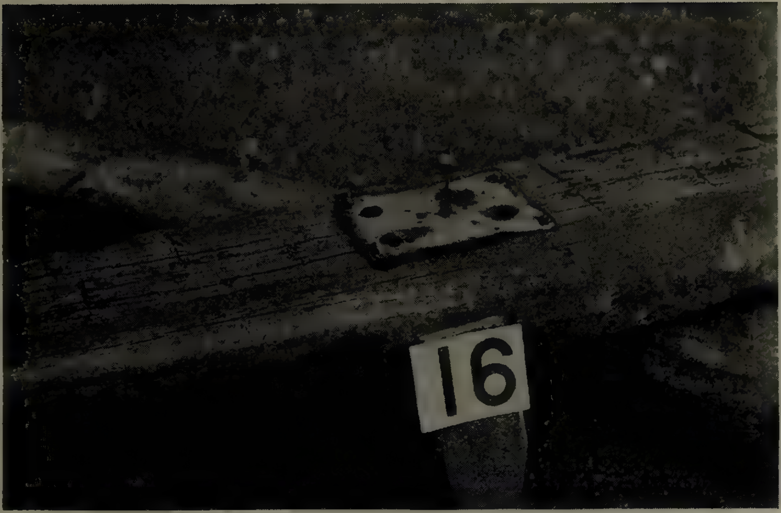

Screw Spike Experiment
No. 7a.
3.9.10
Cow hair pads


Screw Spike Exp.
No. 4a.
3.9.10
Cow hair pads

Cowhair pads
Screw Spike Experiment
No. 6 b.
3. 9. 10.

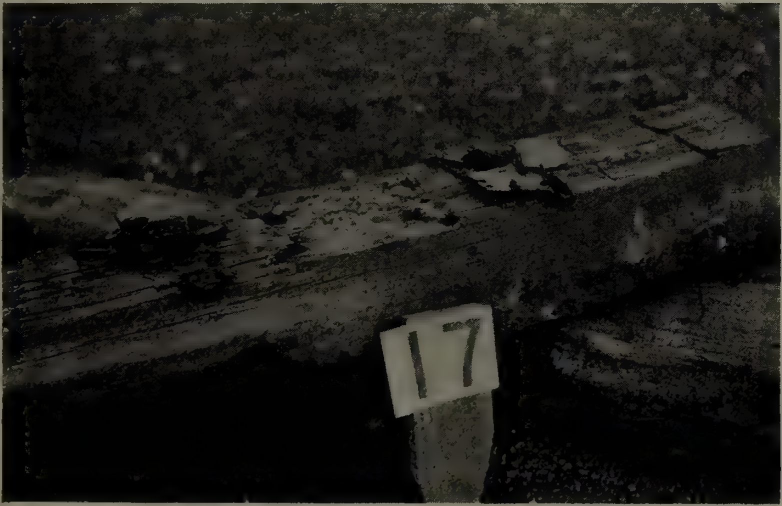
Screw Spike Exp.
No. 6a
3. 9. 10
Cowhair pads

Cow-Hair Pad Placed Under Malleable Iron Tie-Plate.



Type 4a.

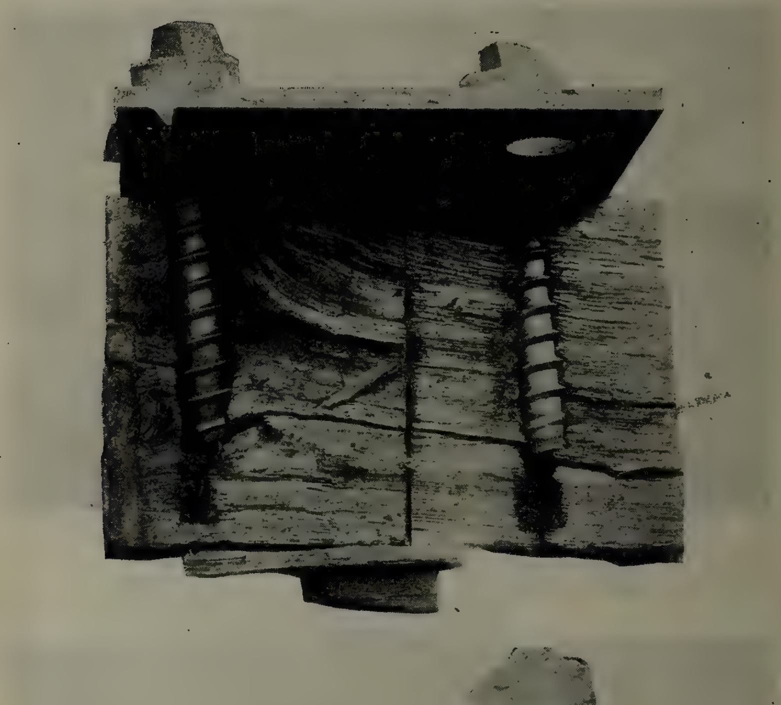
Note cow-hair pad squeezed away from outside end of plate.



Type 4a.

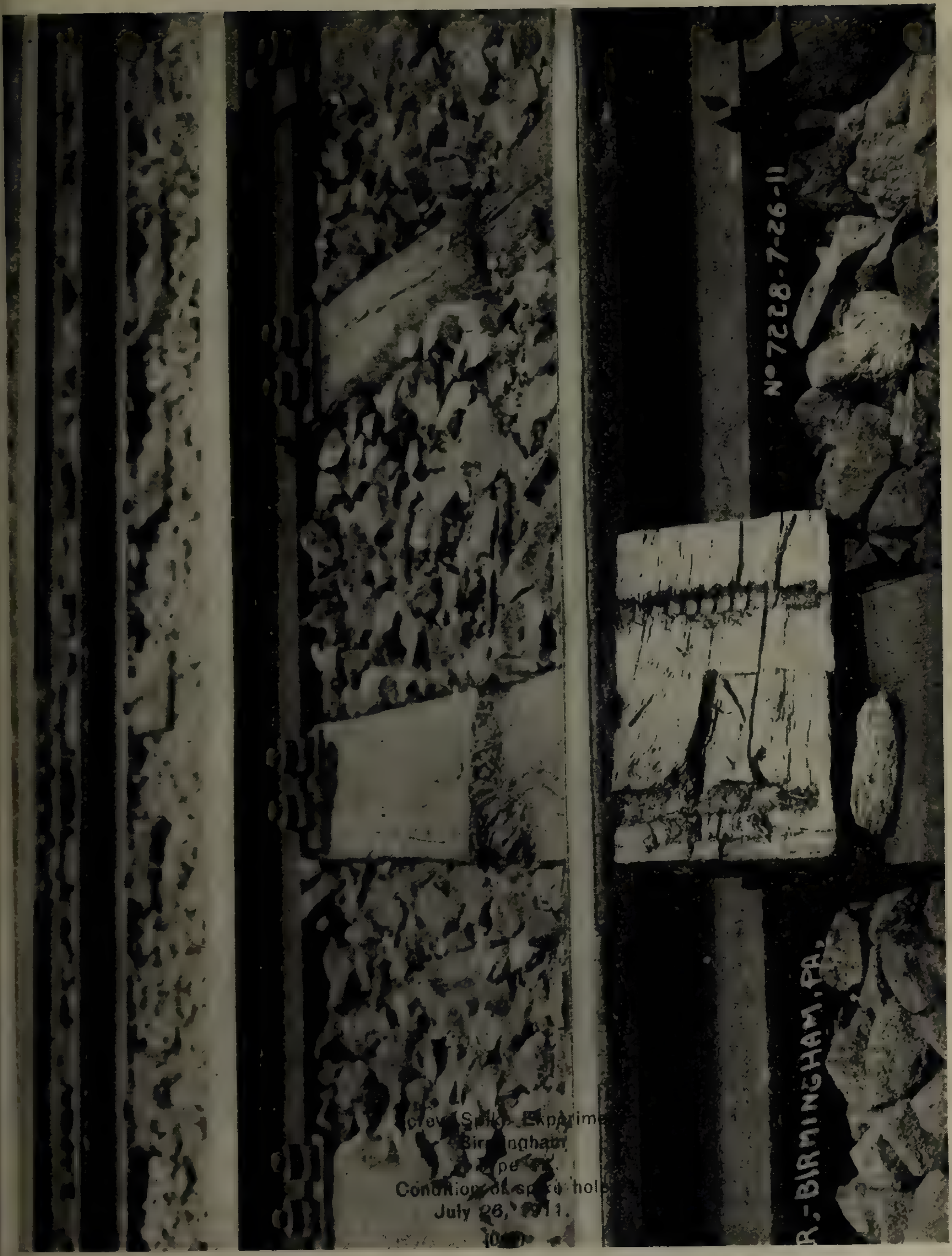
Note pieces of cow-hair pad lying on tie.

Screw-Spike Experiment—Wooster, Ohio.

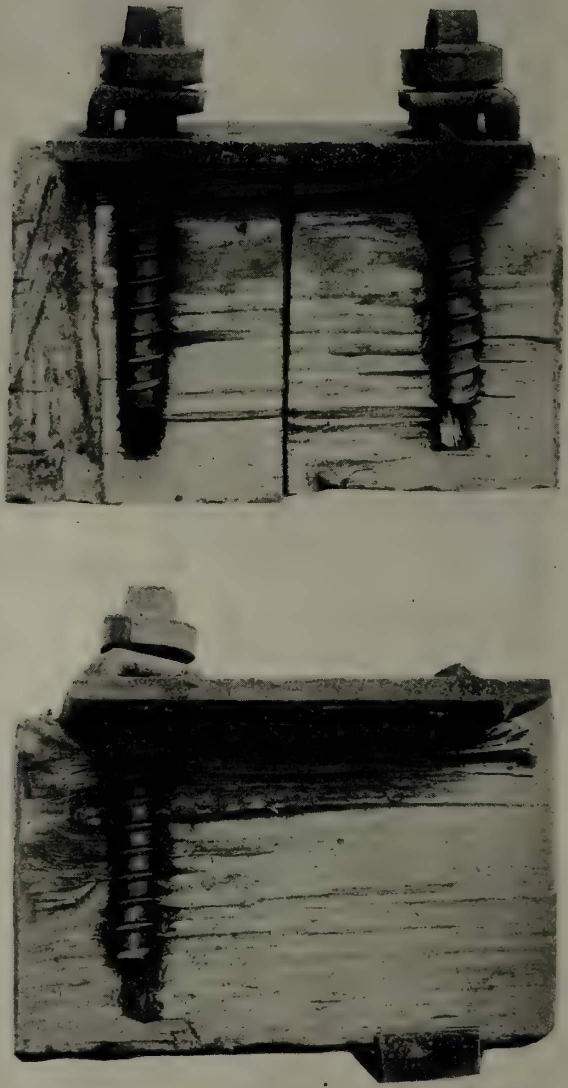


Type 4a.

Condition of Spike Hole.



Type 4a.
Screw-Spike Experiment—Birmingham; July 26, 1911.

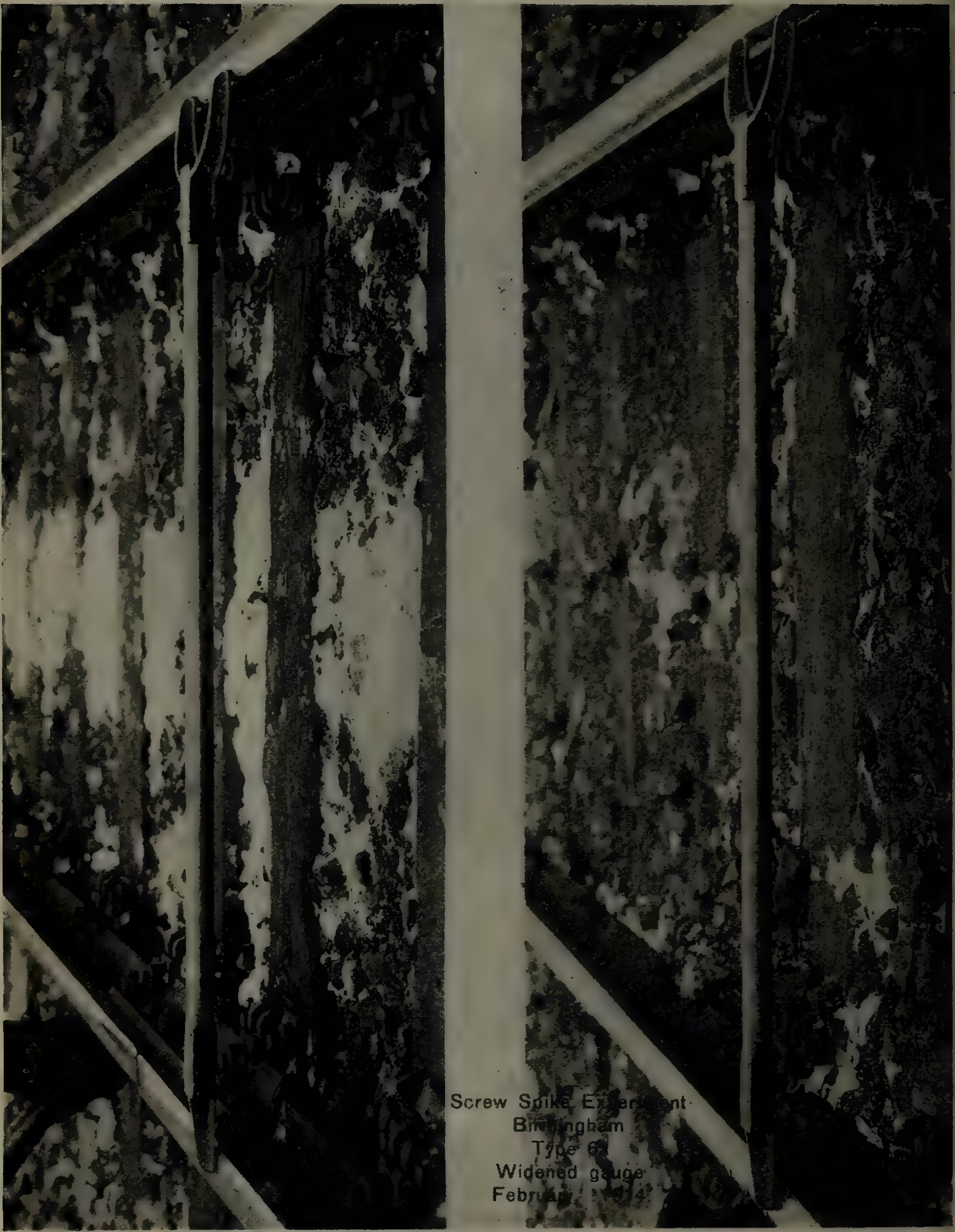


Type 4b.

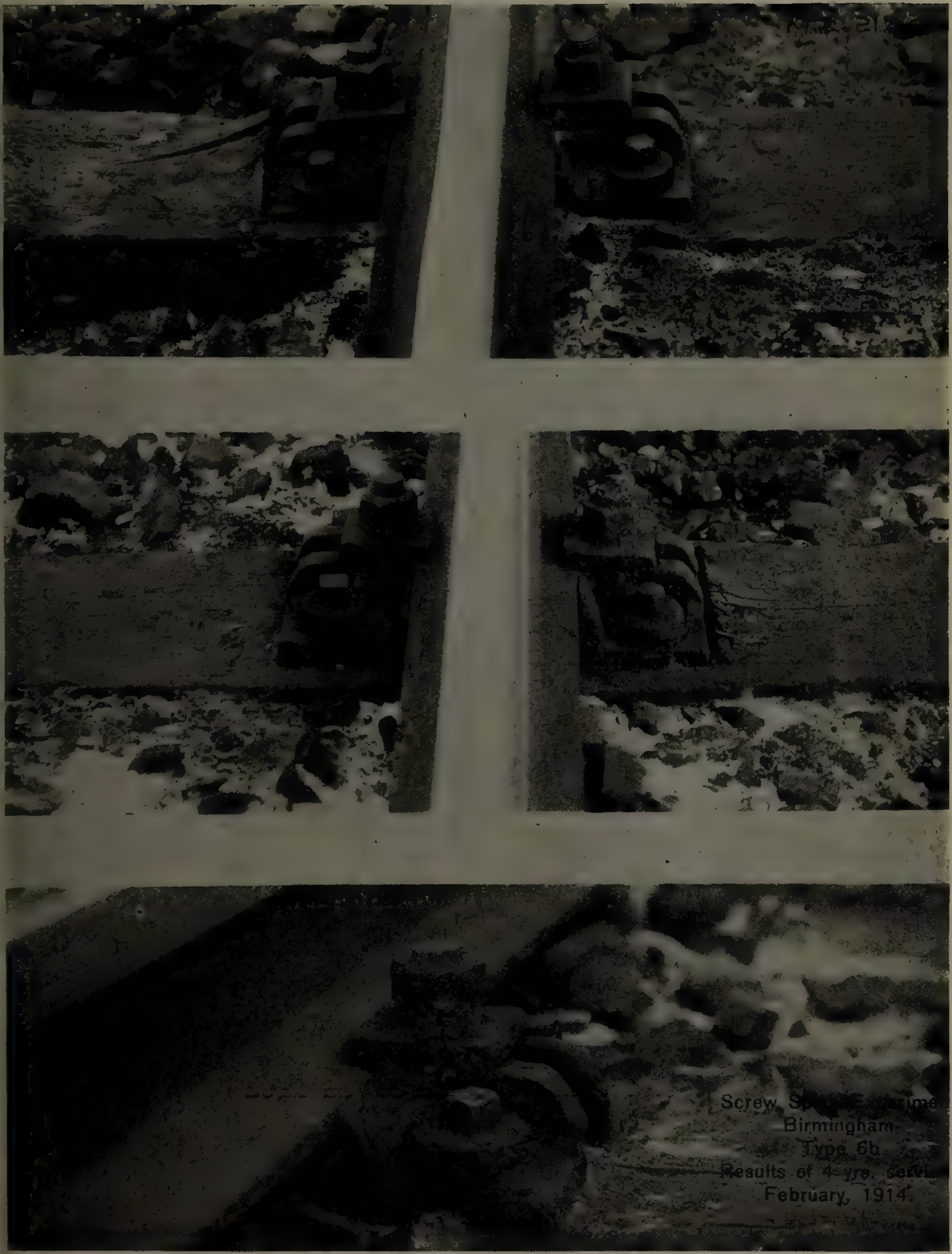
Condition of Spike Holes, July 26, 1911—Birmingham.

Type 6b.

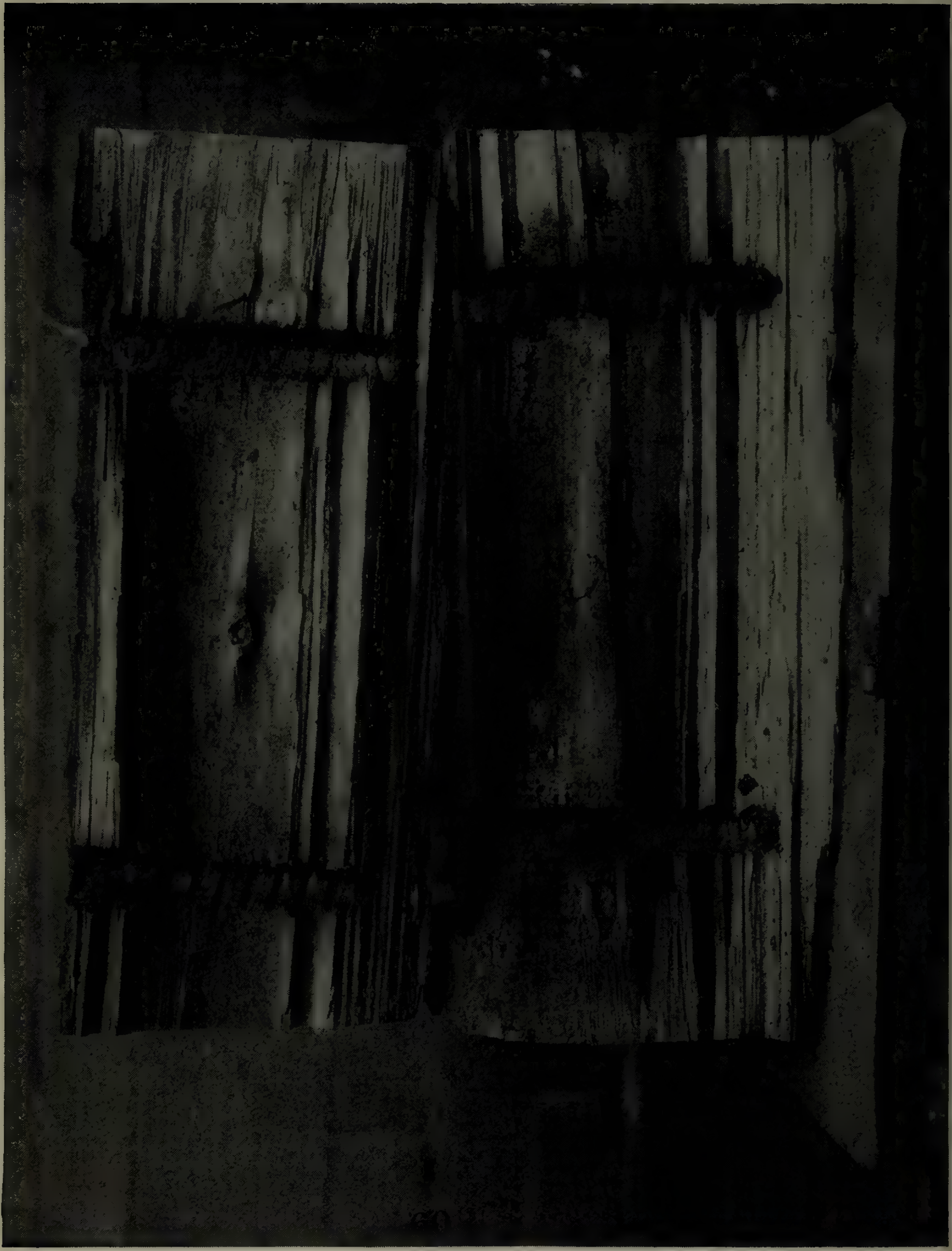
Penetration of Tie-Plate into Tie, February, 1914—Birmingham.


Screw Spike Experiment
Birmingham
Type 6a
Widened gauge
February 1914

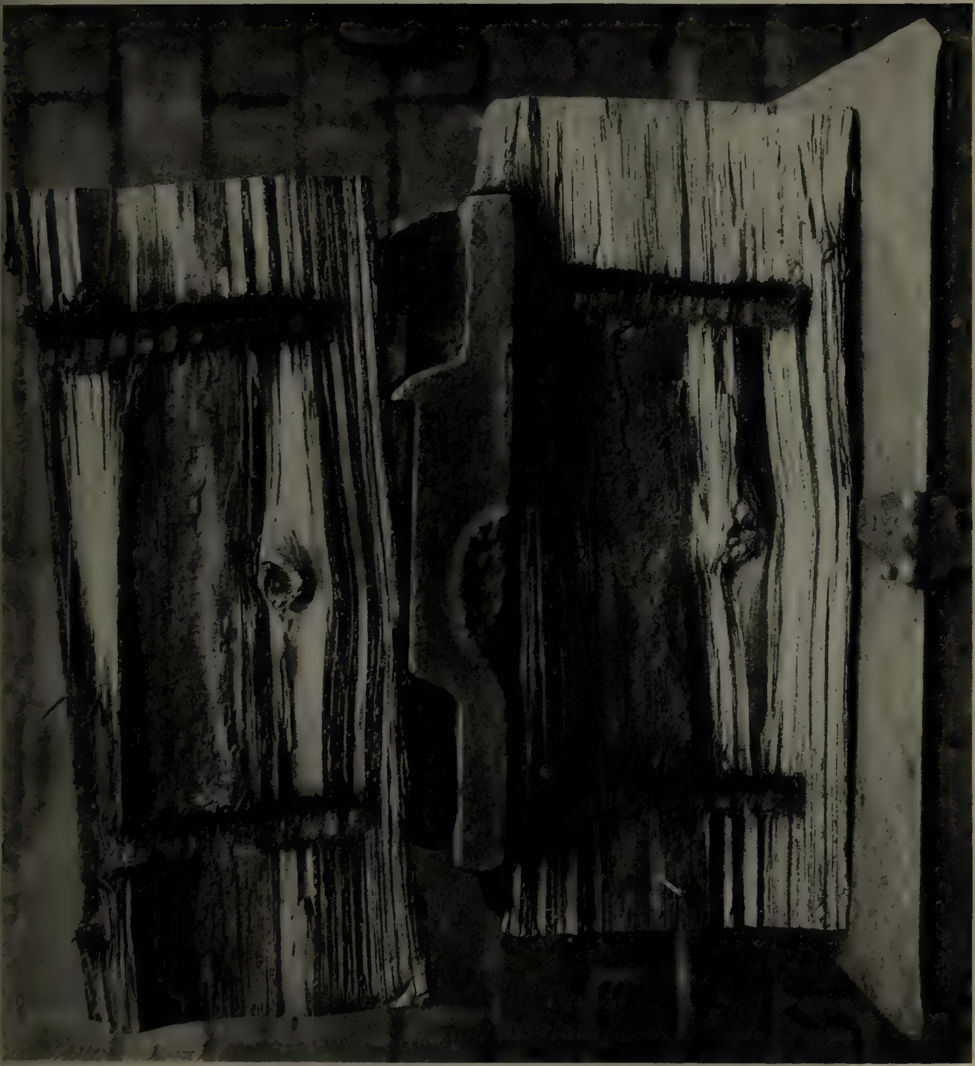
Type 6a.


Screw Spike Experime
Birmingham
Type 6b
Results of 4 yrs. servi
February, 1914

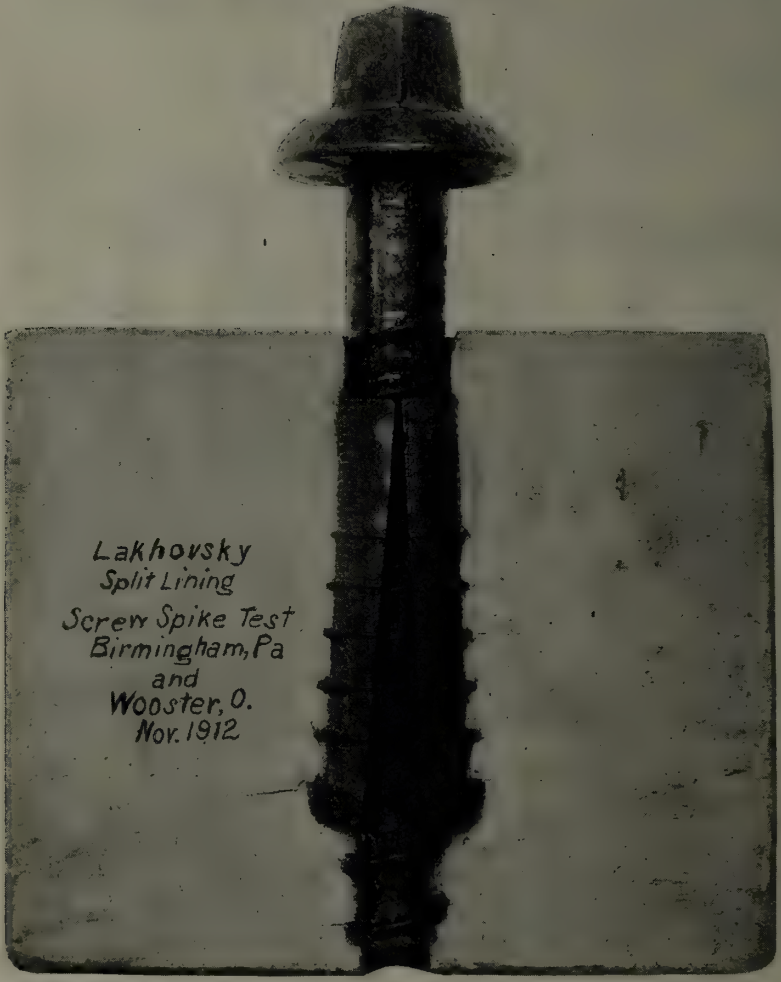
Type 6b.



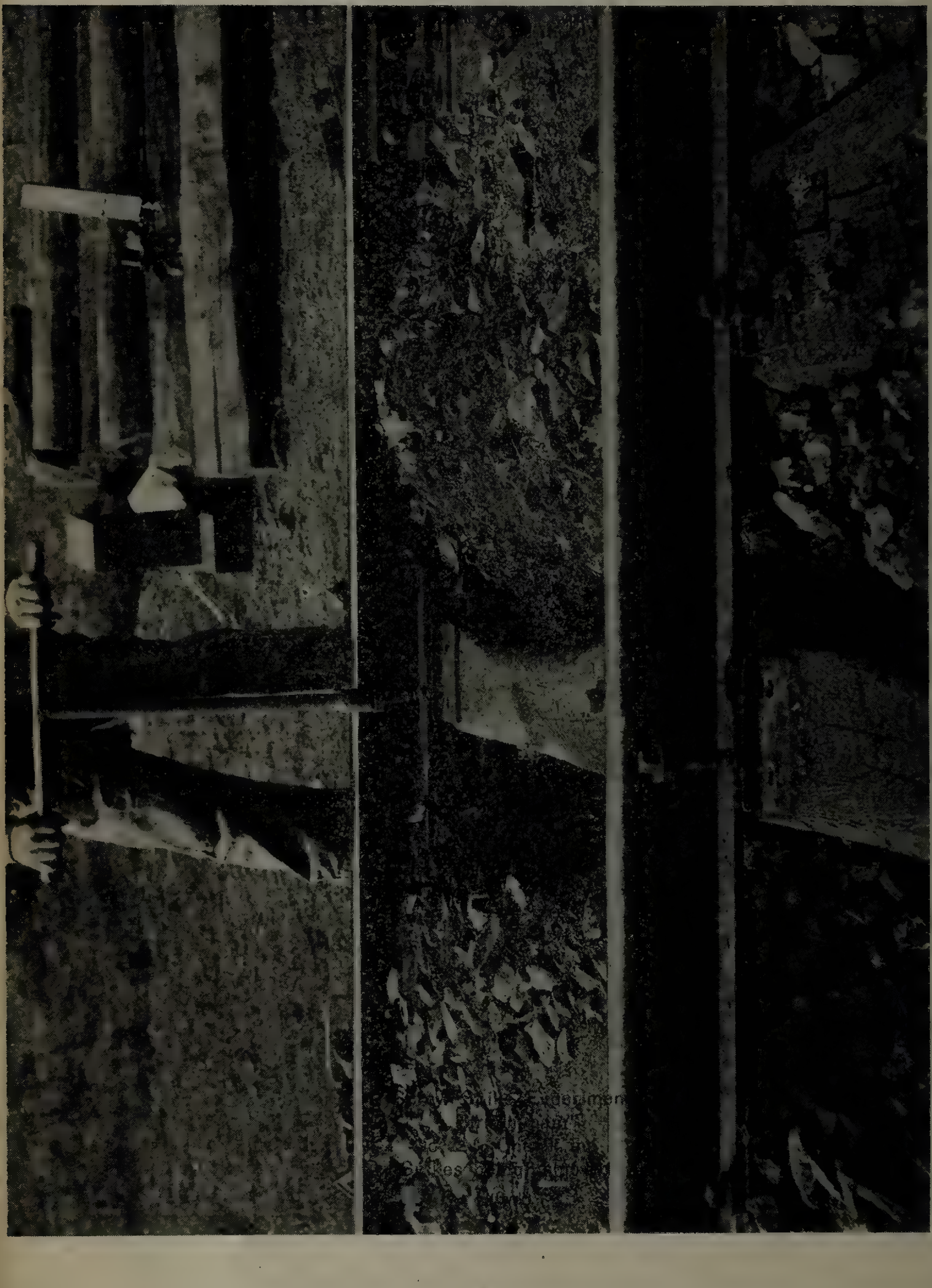
Showing Cutting of Plates into Ties and Destruction of Screw Threads in Wood.



Showing Cutting of Plates into Ties and Destruction of Screw Threads in Wood.


Lakhovsky
Split Lining
Screw Spike Test
Birmingham, Pa
and
Wooster, O.
Nov. 1912

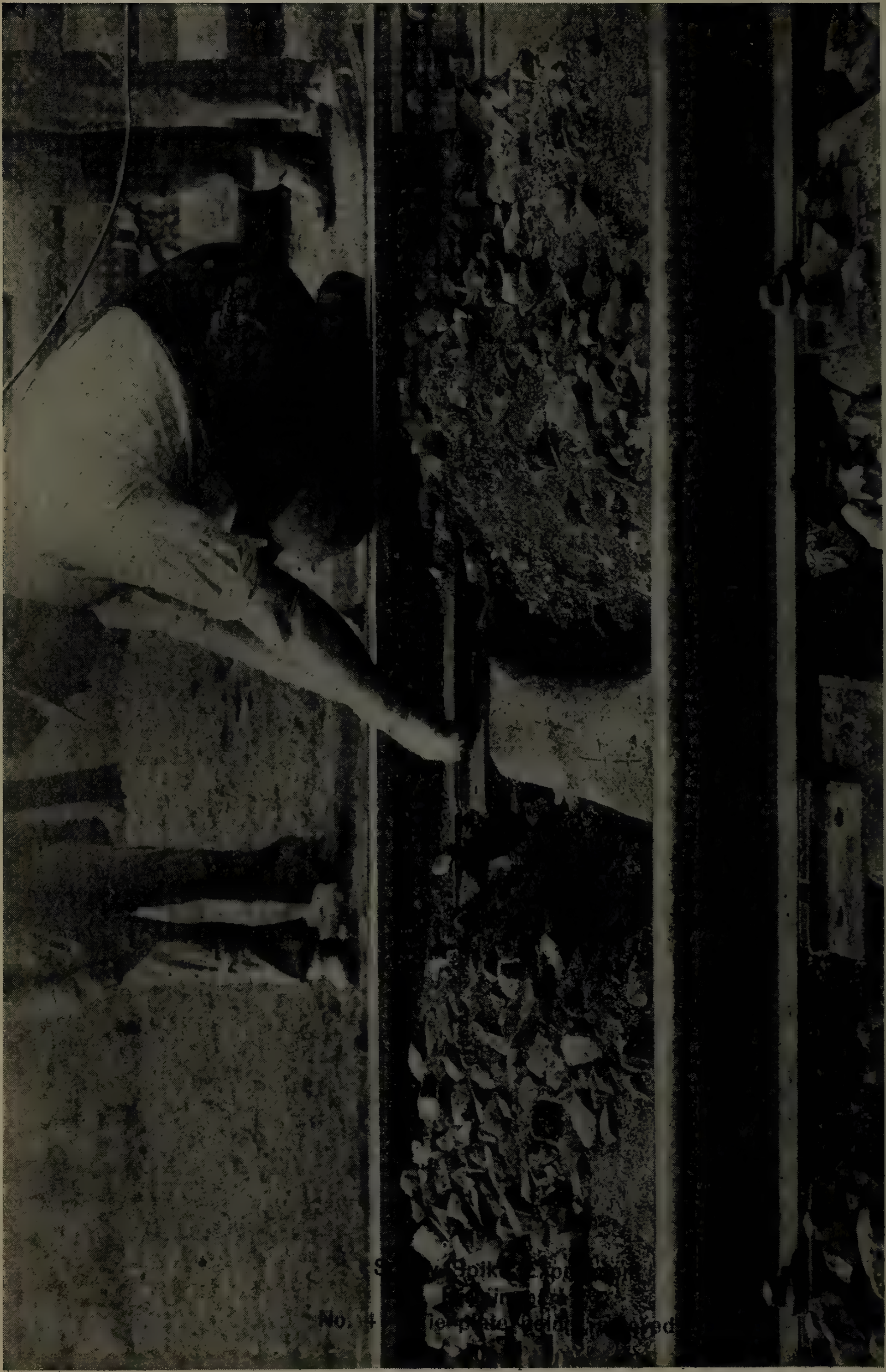
(First Stage.)



(Second Stage.)

One of the Spikes Being Removed.

(Third Stage.)
TIE BEING SHIFTED.



(Fourth Stage.)
TIE-PLATE BEING REMOVED.

(Fifth Stage.)

HOLE BEING REAMED.

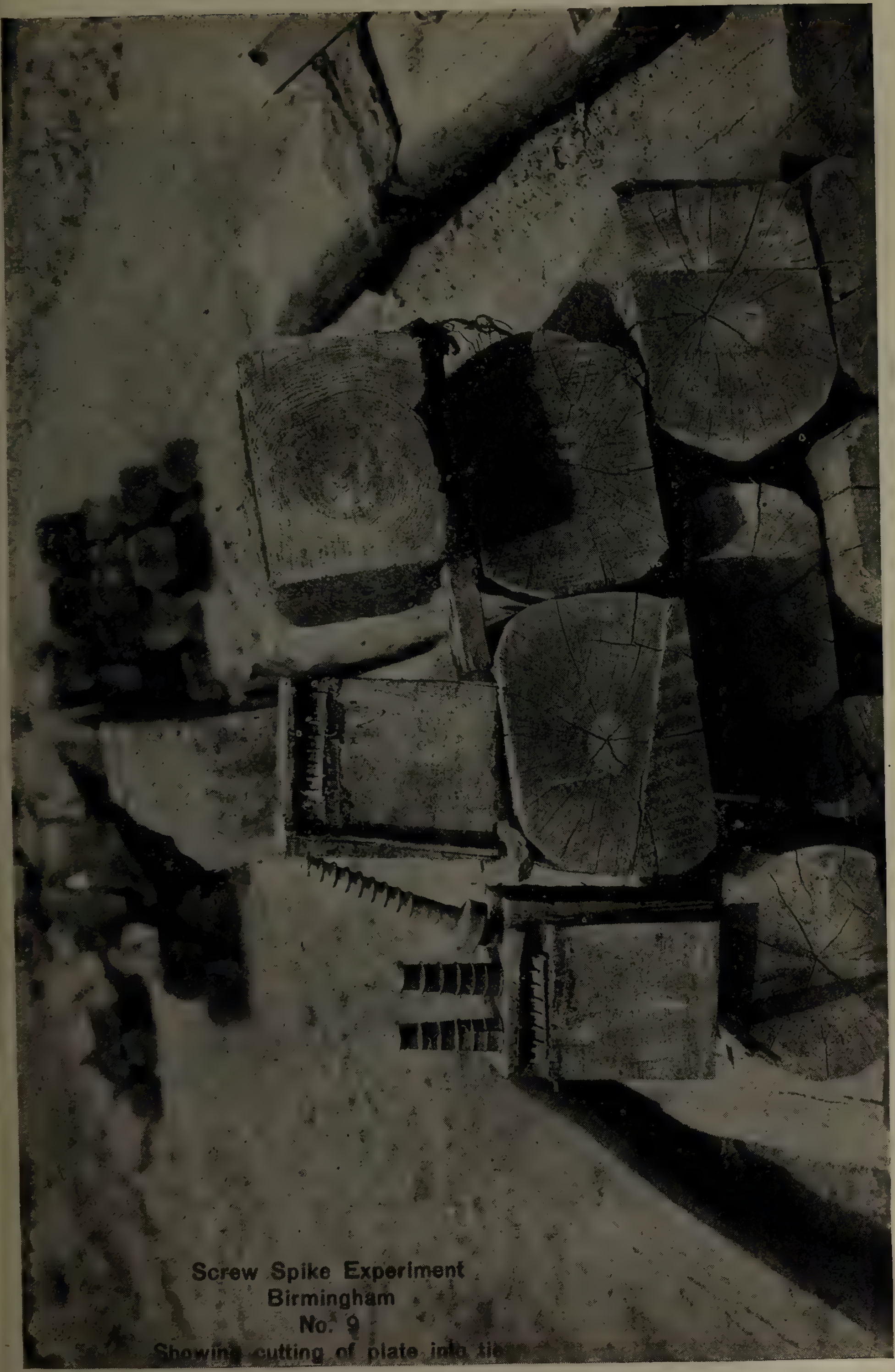
(Sixth Stage.)

Lining Being Applied.

(Seventh Stage.)
TIE-PLATE BEING REPLACED.

TIE IN ITS ORIGINAL POSITION WITH SCREW-SPIKE BEING RE-APPLIED.

(Eighth Stage.)



Screw Spike Experiment
Birmingham
No. 9
Showing cutting of plate into ties

(Ninth Stage.)

No. 10 [illegible]

Showing destruction of screw thread [illegible] tie and cutting of plate into [illegible]

Showing Loose Spikes.

Altoona, Pa., July 30, 1915.

Subject: Tests to determine resistance offered in withdrawing screw-spikes from ties.

Mr. J. T. Wallis,
General Superintendent Motive Power.

Dear Sir:—

Replying to your memorandum of July 16th with letter from Mr. G. W. Creighton, General Superintendent, dated July 15th, asking for tests to determine the force necessary to withdraw screw-spikes from plugged holes in cross-ties, we have completed tests on eight cross-ties with the following results:

Cross-tie No. 1. Loblolly Pine Creosoted, Marked Experiment 7-B
Movement Measured from Bottom of Tie

	Spike No.			
Load. Lbs.	*1*	*2*	*3*	*4*
500—0				
1000	0	0	0	0
2000	.30	.025	0	0
2260	Out			
3000		.075	.029	.014
3380		Out		
4000			.045	.029
5000			.074	.045
6000			.106	.071
6450			Out	
7000				.115
7500				Out

Cross-tie No. 2. Loblolly Pine Creosoted, Marked Experiment 7-B

500—0				
1000	0	0	0	0
2000	0	0	.017	.010
3000	0	0	.021	.019
4000	.087	.016	.041	.027
4270	Out			
4710			Out	
5000		.036		.127
5080				Out
6000		.131		
6140		Out		

Cross-tie No. 3. Loblolly Pine Creosoted, Marked Experiment 7-B
Movement Measured from Bottom of Tie

	Spike No.			
Load. Lbs.	*1*	*2*	*3*	*4*
500—0	0	0	0	0
1000	.050	0	0	0
1870	Out			
2000		.015	.010	0
3000		.082	.023	.010
3460		Out		
4000			.029	.016
4840				Out
5000			.051	
5750			Out	

Cross-tie No. 4. Oak Creosoted

500—0				
1000	0	0	0	0
2000	0	0	.020	0
3000	.015	0	.025	.027
4000	.028	.019	.039	.038
4680			–	Out
5000	.038	Out	.054	
6000	.060		.083	
7000	.065		.113	
7710			Out	
8000	.092			
9000	.205			
9430	Out			

Cross-tie No. 5. Oak Creosoted, Marked Experiment 7-A

500—0				
1000	.027	0	0	0
1380	Out			
2000		0	.010	.010
3000		0	.044	.045
3700			Out	
4000		.010		.105
4750				Out
5000		.020		
6000		.039		
7000		.082		
8000		.128		
8870		Out		

Cross-tie No. 6. Mixed Oak Creosoted, Marked Experiment 7-A
Movement Measured from Bottom of Tie

	Spike No.			
Load. Lbs.	1	2	3	4
500—0	0	0	0	0
1000	0	0	0	0
2000	.008	0	0	.013
2730				Out
3000	.019	.010	.012	
4000	.034	.023	.027	
5000	.061	.034	.039	
6000	.127	.047	.052	
6110	Out			
7000		.055	.088	
7830			Out	
8000		.077		
9000		.106		
10000		.233		
10100		Out		

Cross-tie No. 7. Loblolly Pine Creosoted
Movement Measured from Bottom of Tie

	Spike No.			
Load. Lbs.	1	2	3	4
500—0	0	0	0	0
1000	.041	.037	.036	.011
1750	Out			
2000		.318	.158	.041
2140			Out	
2540		Out		
2780				Out

Cross-tie No. 8. Mixed Oak Creosoted

Movement Measured from Bottom of Tie

	Spike No.			
Load. Lbs.	*1*	*2*	*3*	*4*
500—0	0	0	0	0
1000	0	0	0	0
2000	.006	.011	.008	.008
3000	.013	.019	.016	.046
4000	.022	.059	.026	Out at 3870 lbs.
4940		Out		
5000	.030		.039	
6000	.038		.051	
7000	.050		.071	
7960			Out	
8000	.086			
8810	Out			

When these ties were received, the spikes were screwed down tight on to the tie-plates and it was necessary for us to remove the spikes and take off the tie-plates, screwing the spikes back to their original depth in order that there might be sufficient distance between the head of the spike and the tie to allow of gripping on the test machine. The screw-spikes were all old, and it was noticed that there was considerable difference in the appearance and depth of the thread on the various spikes, some of them being very badly corroded. Tests were made with the 1 inch screw-spikes only, these were 6 inches long and screwed into the plugs 5 inches deep. In all cases the plugs pulled out either entirely or partially along with the screw-spike.

For comparison with the screw-spikes, I give below results of tests made on straight nail-spikes:

Movement Measured from Bottom of Tie

Kind of Tie—	*Oak Creosoted*				*Mixed Oak Creosoted*				*Loblolly Pine Creosoted*			
Spike No.— Load. Lbs.	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
500—0	0	0	0	0	0	0	0	0	0	0	0	0
1000	0	.002	.005	.003	.002	.003	.001	.004	.003	.002	.003	.004
2000	.007	.005	.010	.008	.005	.008	.007	.009	.006	.008	.013	.009
2720									Out			
3000	.015	.009	.017	.012	.010	.013	.011	.015		.018	.027	.016
3760											Out	
3840								Out				
4000	.026	Out	.025	.018	.018	.020	.016			.048		.030
4480										Out		
4900												Out
5000	.038		.030	.026	.084	.029	.025					
5420				Out								
5480					Out							
5720	Out											
6000			.036			.045	.036					
6690			Out									
6960							Out					
7000						.063						
8000						.084						
8760						Out						

Summarizing the results obtained on both screw- and nail-spikes, we have the following comparison:

	Screw	*Nail*
Number tested—	32	12
Pulling load below 2000 lbs.	3	0
“ “ between 2000 and 3000 lbs.	5	1
“ “ “ 3000 “ 4000 “	4	3
“ “ “ 4000 “ 5000 “	7	2
“ “ “ 5000 “ 6000 “	2	3
“ “ “ 6000 “ 7000 “	3	2
“ “ “ 7000 “ 8000 “	4	0
“ “ “ 8000 “ 9000 “	2	1
“ “ “ 9000 “ 10000 “	1	0
“ “ “ 10000 “ 11000 “	1	0

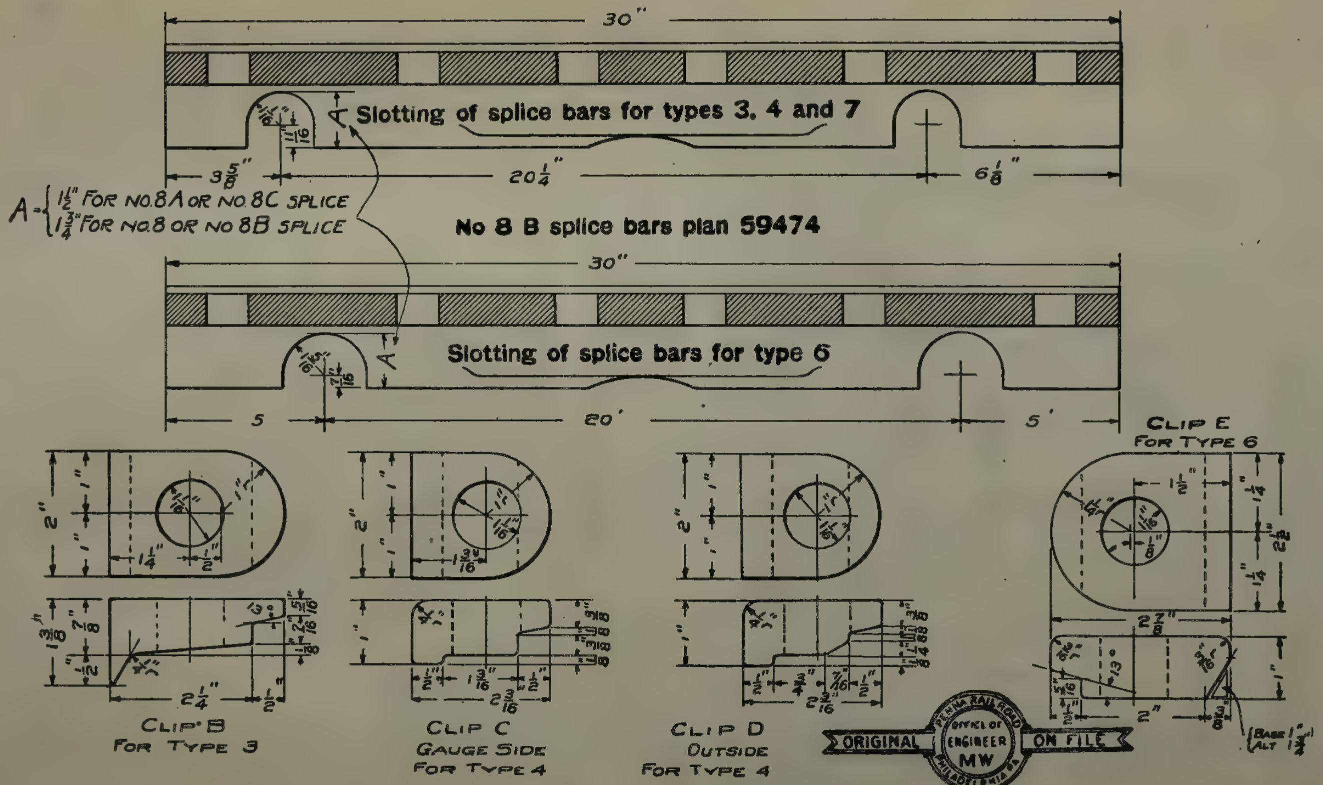
The above figures seem to be too unequal to average for pulling load, but by inspection it will be seen that the majority of the screw-spikes pulled out with from 4000 to 5000 lbs. load, and in the case of the nail-spikes 50 per cent. were below and 50 per cent. above 5000 lbs.

Judging from these tests, it would seem as if the screw-spikes in plugged holes may be considered to have about the same holding power as the average standard nail-spike.

We have the cross-ties, spikes and tie-plates in the laboratory, and would be glad to be advised disposition of this material.

Yours respectfully,

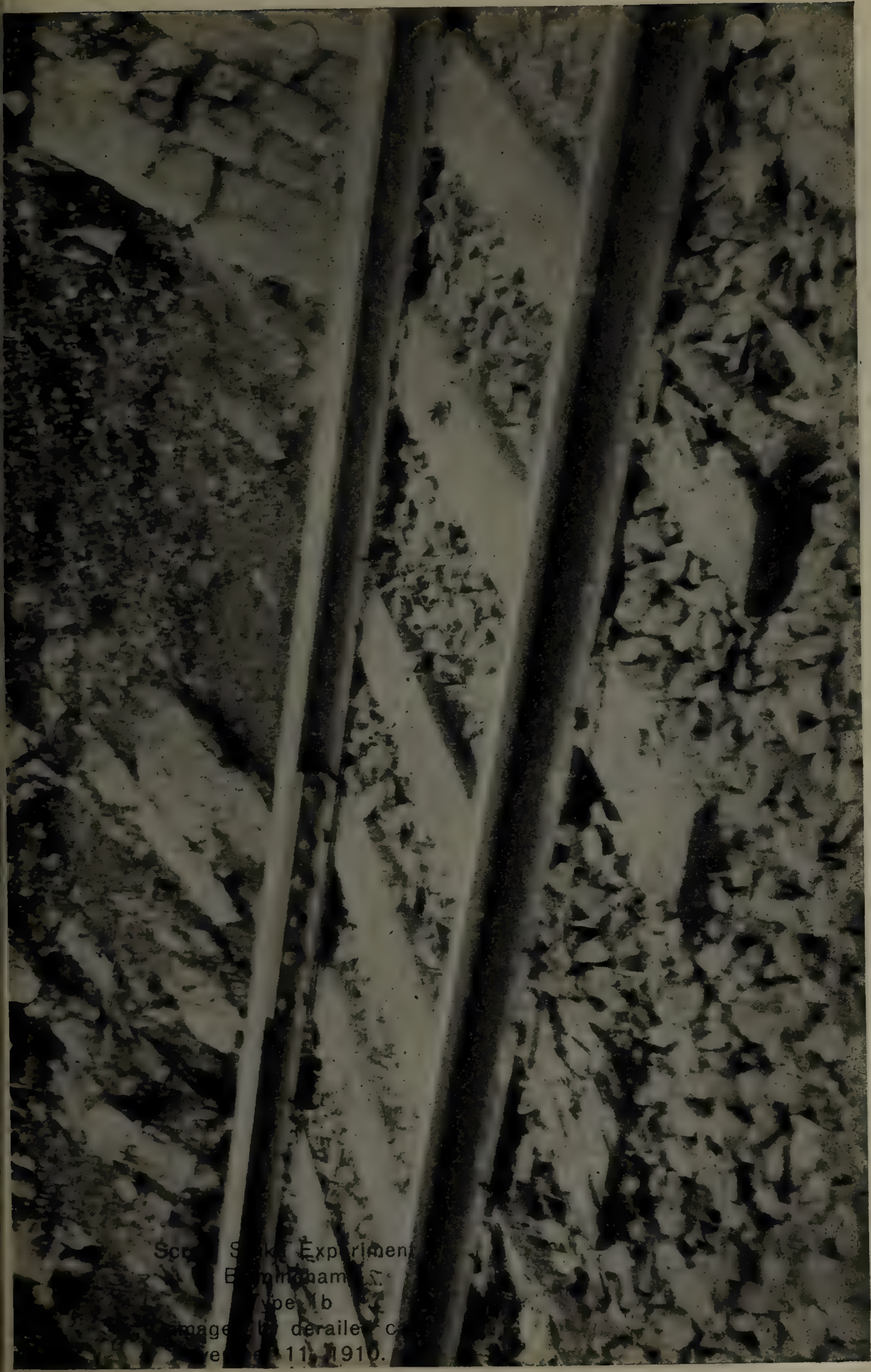
(Signed) C. D. Young,
Engineer of Tests.


30"
Slotting of splice bars for types 3, 4 and 7
A
3 5/8"
20 1/4"
6 1/8"
A = { 1 1/2" FOR NO. 8A OR NO. 8C SPLICE; 1 3/4" FOR NO. 8 OR NO 8B SPLICE }
No 8 B splice bars plan 59474
30"
Slotting of splice bars for type 6
5
20'
5'
CLIP B
FOR TYPE 3
CLIP C
GAUGE SIDE
FOR TYPE 4
CLIP D
OUTSIDE
FOR TYPE 4
CLIP E
FOR TYPE 6
ORIGINAL
ON FILE
MW
(BASE 1"; ALT 1 3/4")

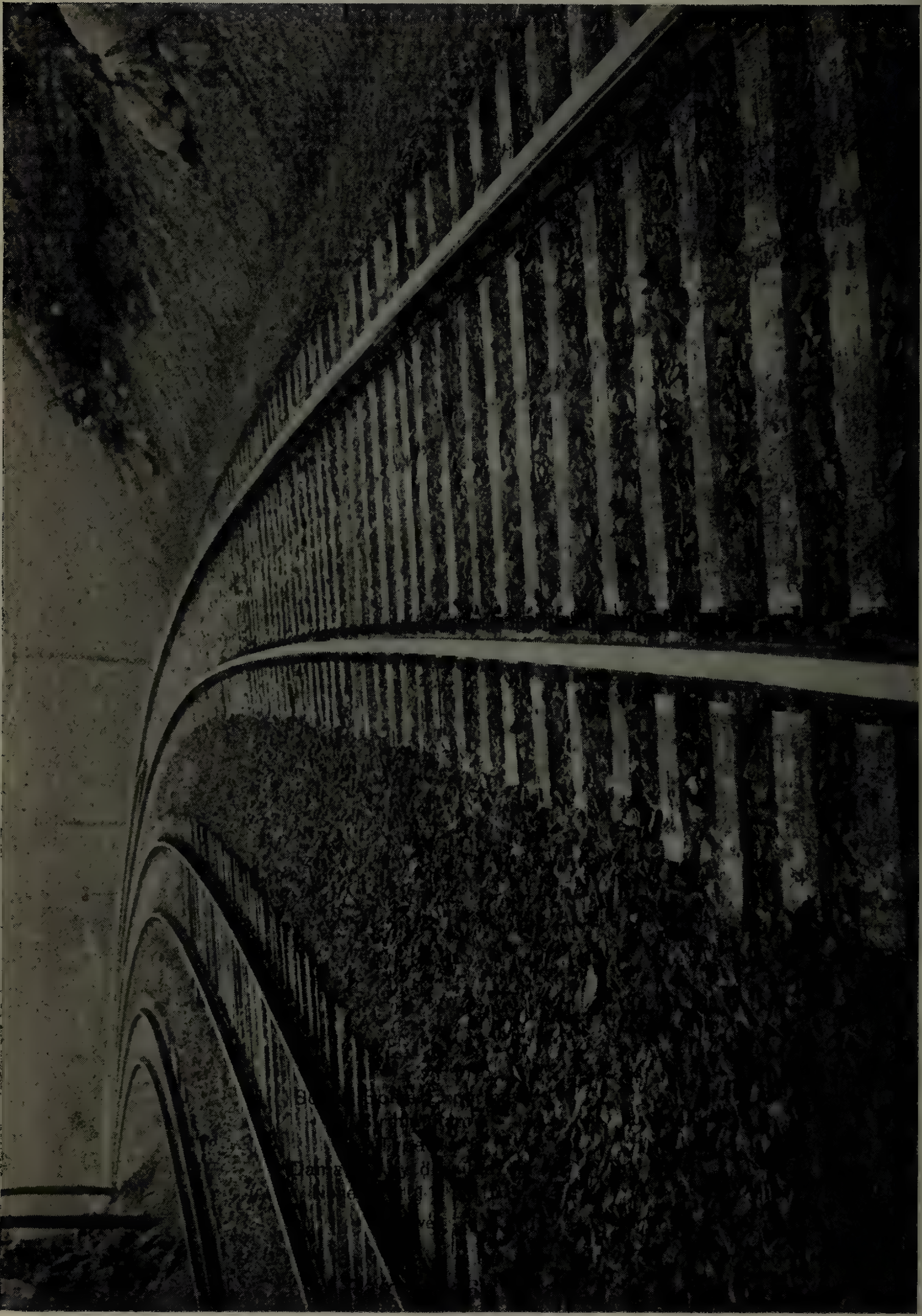
60109
PENNA. SYSTEM
SCREW SPIKE TEST
CLIPS AND SLOTTING OF SPLICE-BARS
TYPES 3, 4, 6, & 7

Approved October 27 1910
Eng'r M. W. P. R. R.

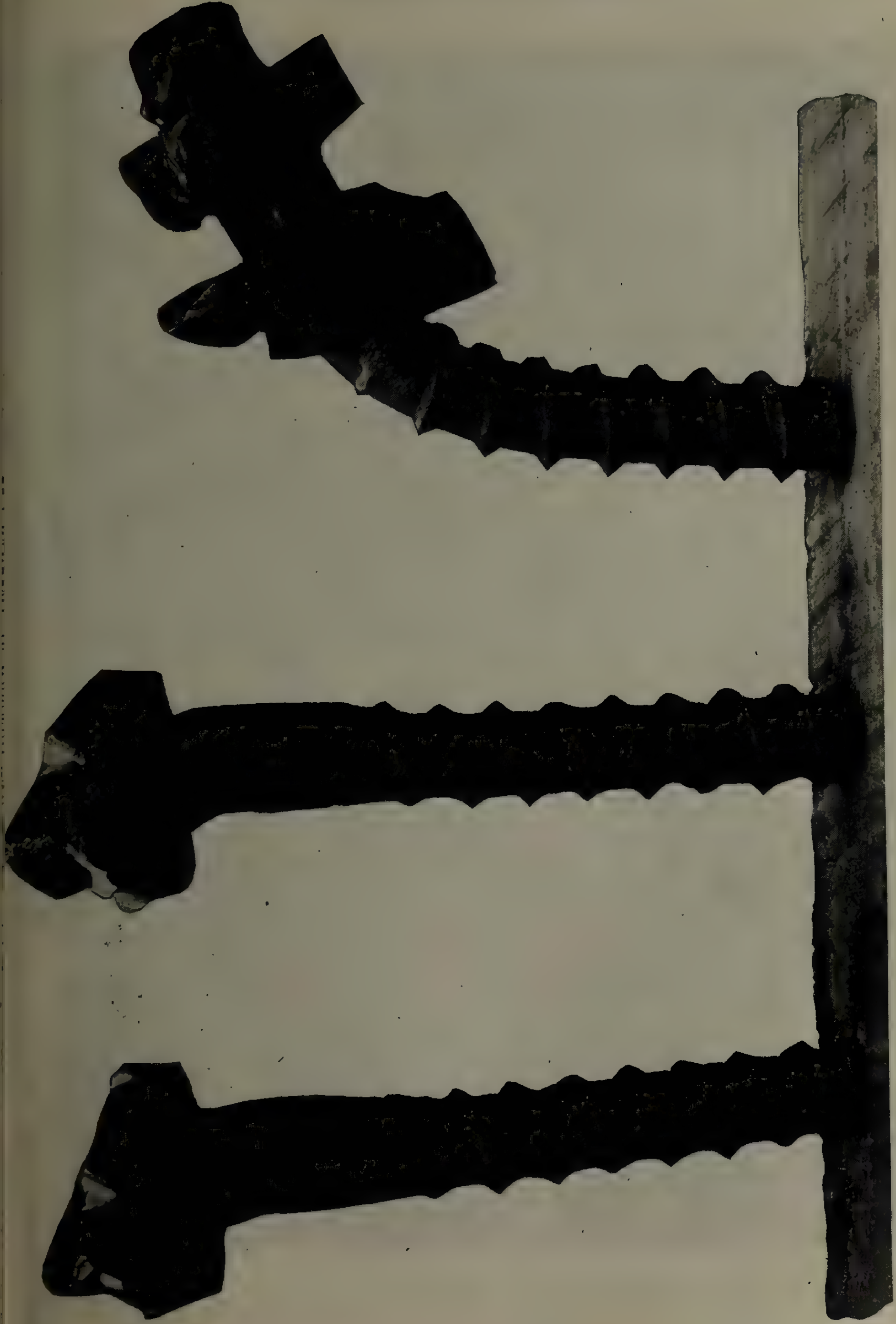
Approved October 27. 1910
Joseph T Richards
Chairman S. S. Com.



TYPE 1B. DAMAGED BY DERAILED CAR.

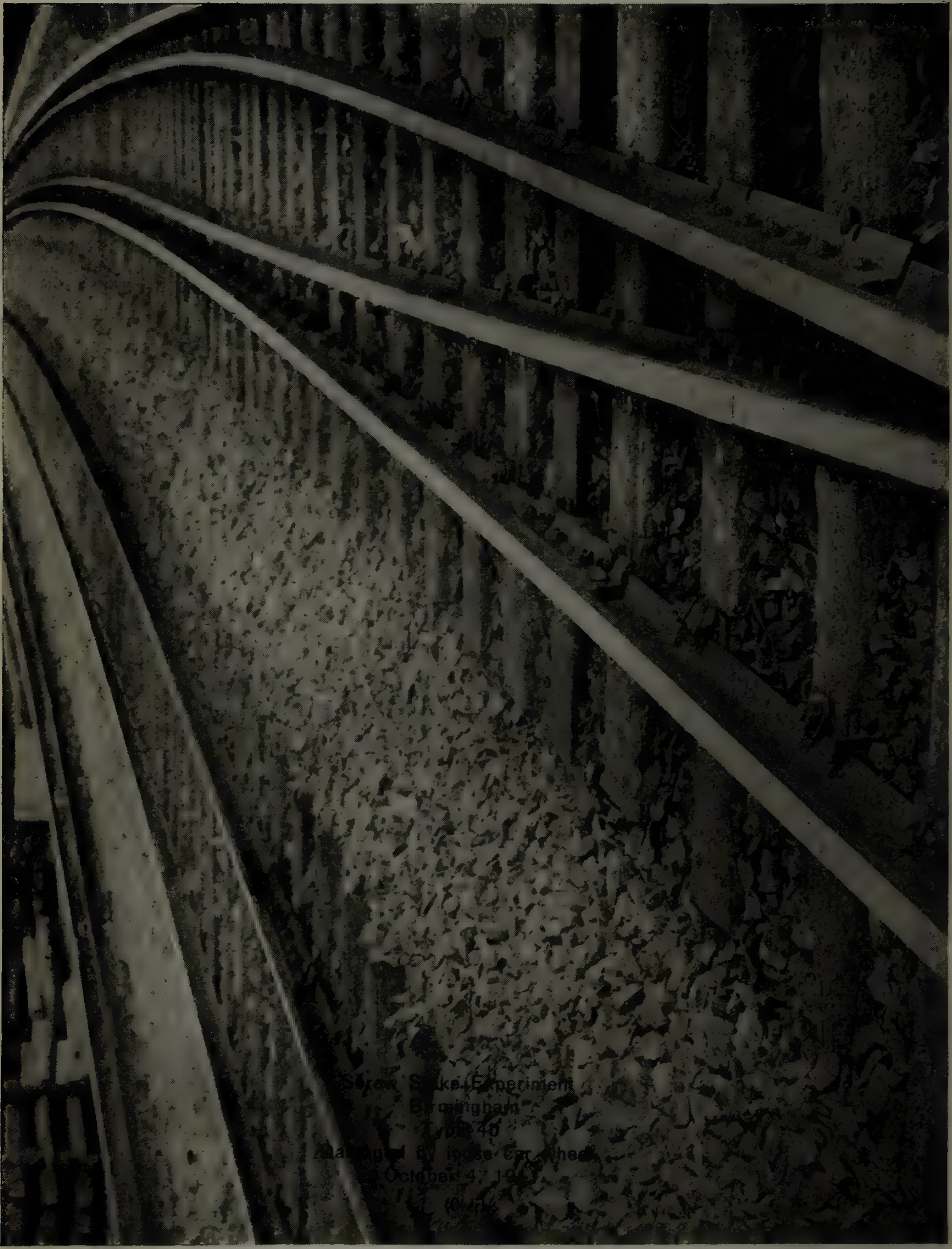


TYPE 4A. DAMAGED BY DERAILED CAR.

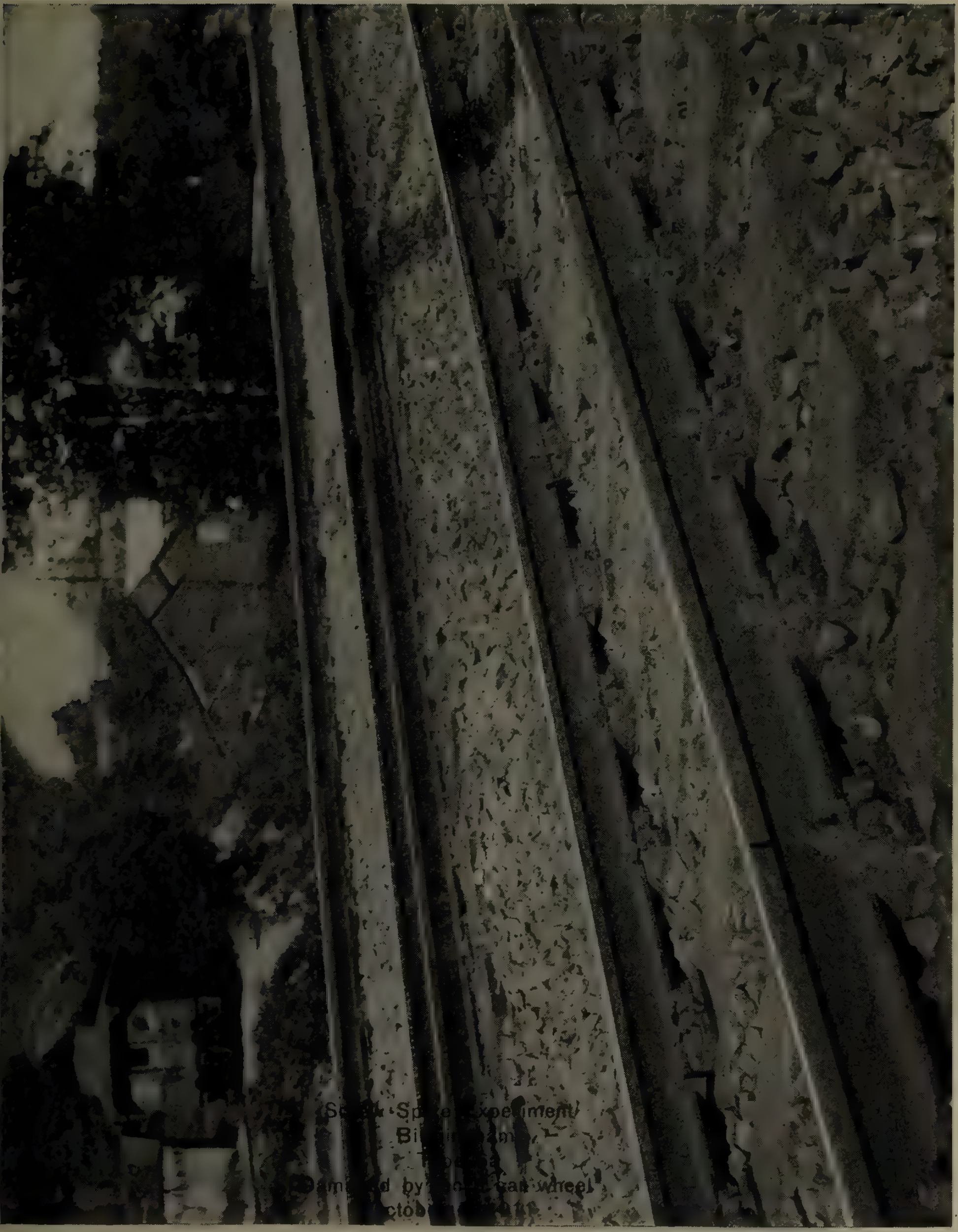


Birmingham.

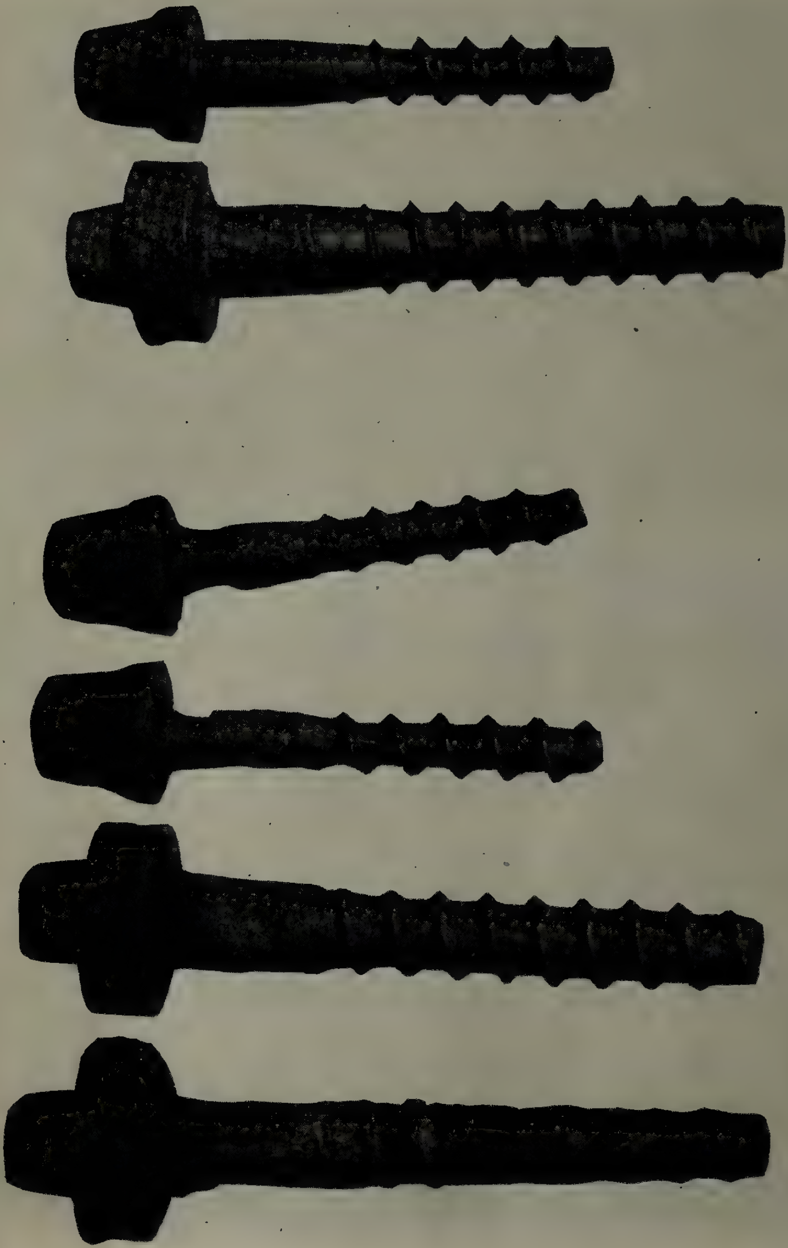
Screw-Spikes Damaged by Loose Car Wheel, October 4, 1911.



TYPE 4B. DAMAGED BY LOOSE CAR WHEEL.

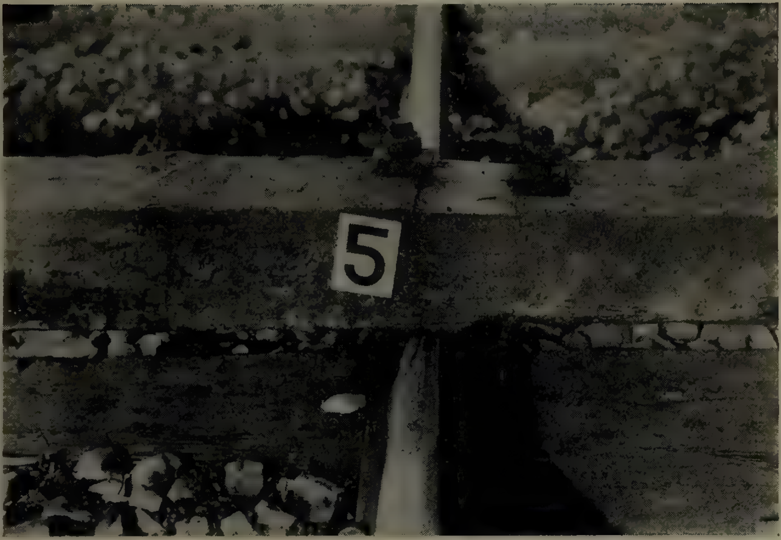


Type 6A. Damaged by Loose Car Wheel.

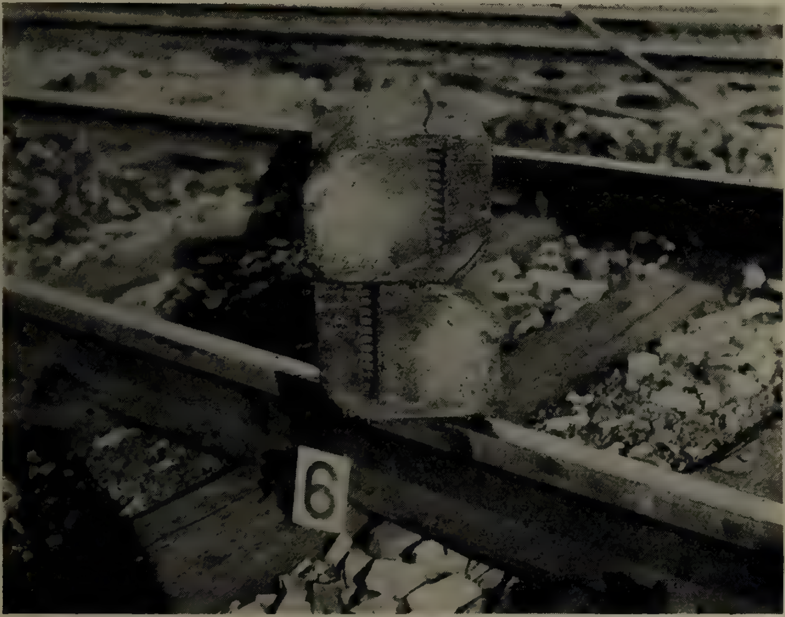


Birmingham.

TYPE 7B. CONDITION OF SCREW-SPIKES AFTER SERVICE OF 5 YEARS AND 8 MONTHS.

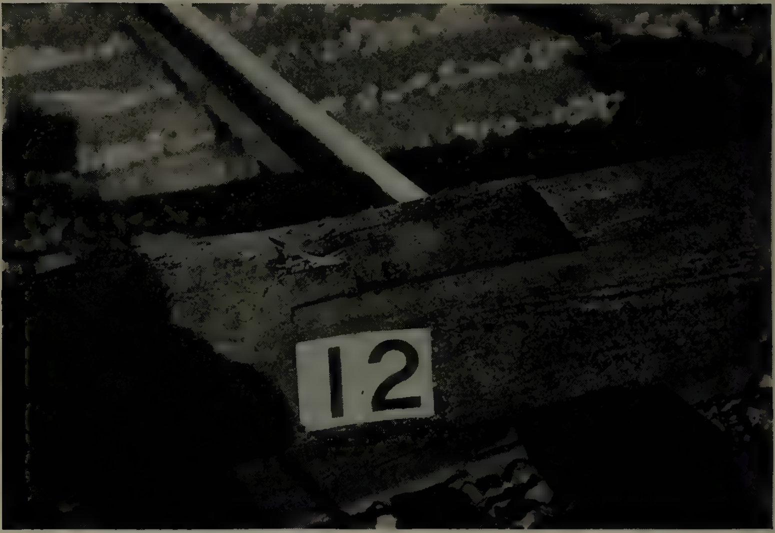


Cutting of Tie by Rail and Abrasion of Lower Edge of Tie Outside of Rail.

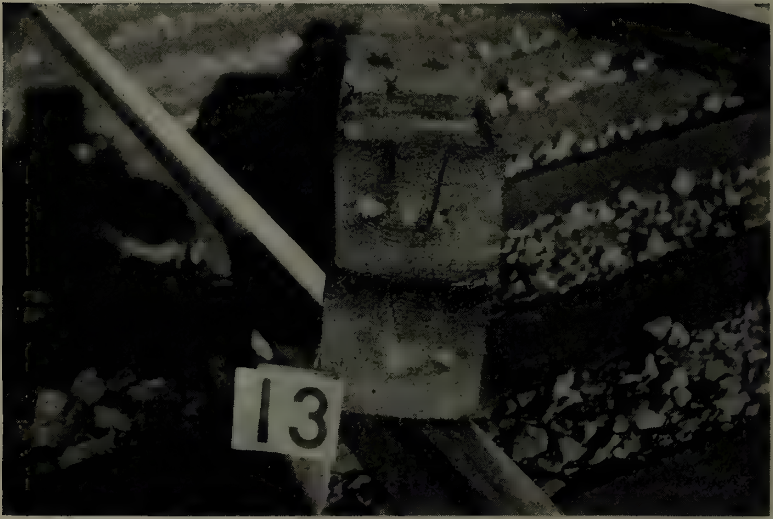


Type 3. Wooster.

Good Condition of Spike Hole. Spike Had Penetrated to Bottom of Hole.



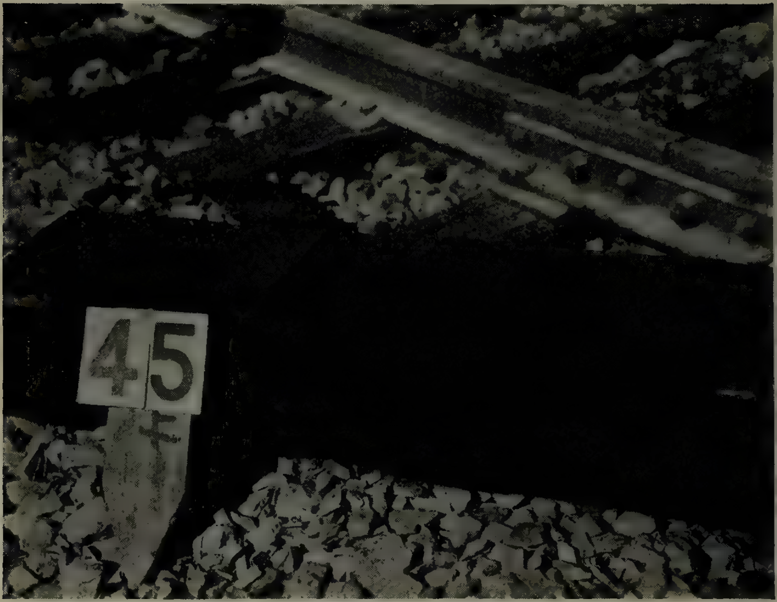
Tie Shown With Tie-Plate Removed.



Type 1b. Wooster.
Tie Shown Cut Through Spike Holes Inside of Low Rail

Screw-Spikes With Clips.

Type 5a. Wooster.
Tie No. 23, Above, Removed From Track.



Type 7b. Wooster.

Greater Cutting Into Tie Under Outer Edge of Plate.

PROPER SIZE OF TIE-PLATES.

December 13, 1912.

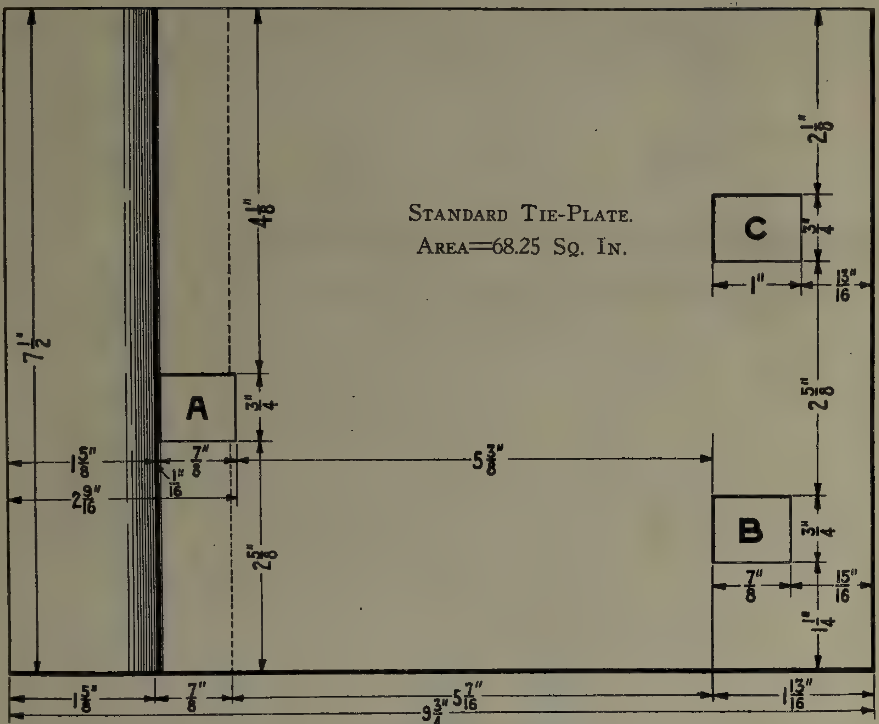
Mr. Samuel Rea,
Vice-President.

Dear Sir:—

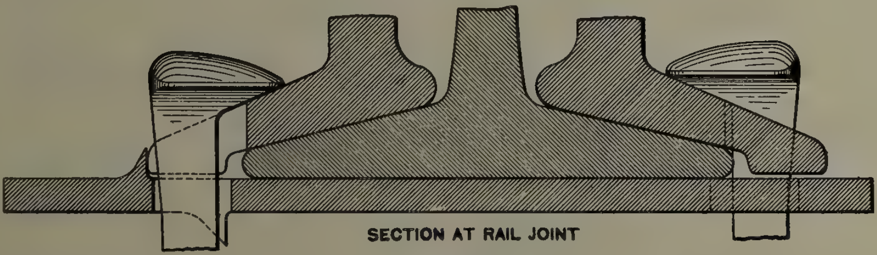
In reply to your note of December 11th, concerning tie-plates; attached is a blueprint, p. 91, showing the type of tie-plate that has been standard for some years—the size was increased from 63 square inches to 68.25 square inches two years ago. Print, p. 92, shows the tie-plate that is in use in the New York Tunnels, with an area of 94.5 square inches. Print, p. 93, is a study of a tie-plate with 99.75 square inches, of the general type of the New York Tunnel plate, modified so that either screw or driven spikes can be used, and a shoulder on the inside of the rail in order to hold the tie-plate in position. We have a few of this latter type in track for trial. The ties in the New York Tunnels were selected ties.

The ties we buy generally have the following face dimensions: Pine, 9 inches; oaks and other hardwoods, sawed, 8 inches; oaks and other hardwoods, hewn, 7 inches. The hardwood hewn ties are falling off in number, most of the ties now being sawed; therefore, we are getting probably 70 per cent. of our ties with eight inches or more face, which, if continued, may permit us to increase the width of the tie-plate above seven inches.

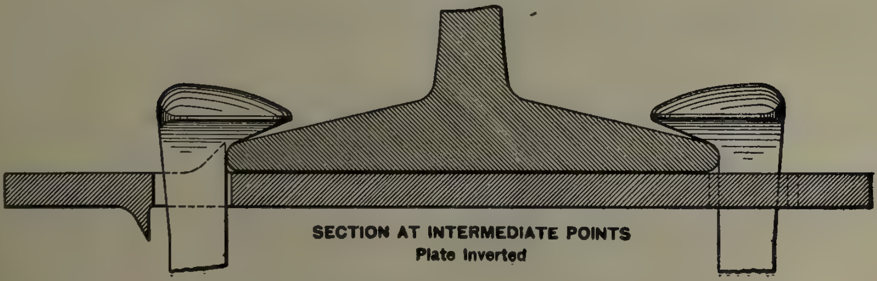
Our bridge ties are all sawed and a large number creosoted, and are ten inches face. As these ties cost four or five times as much as track ties, we propose in the future to have the tie-plates for bridge ties made



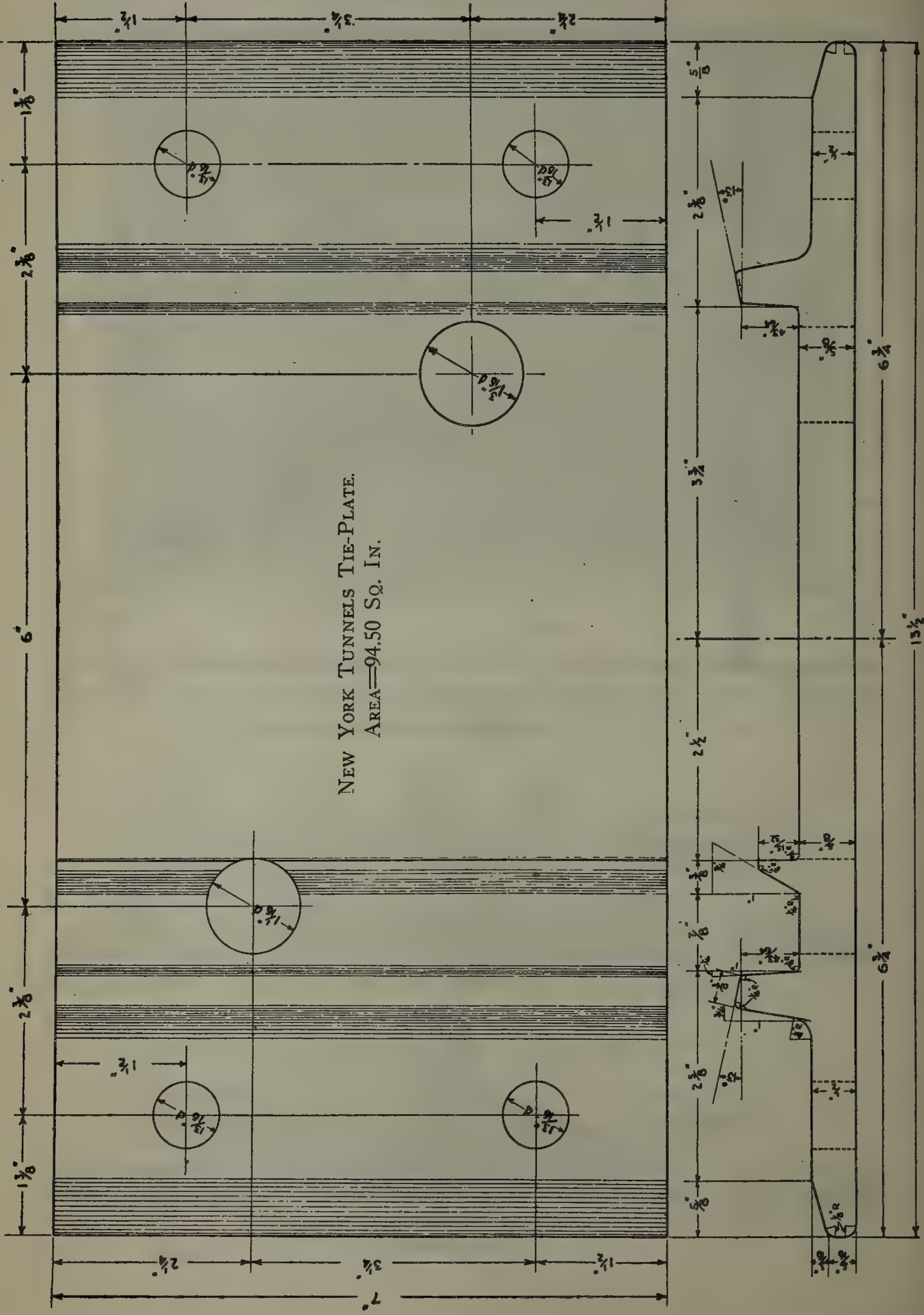
PUNCHING FOR 100 LB. TIE PLATE



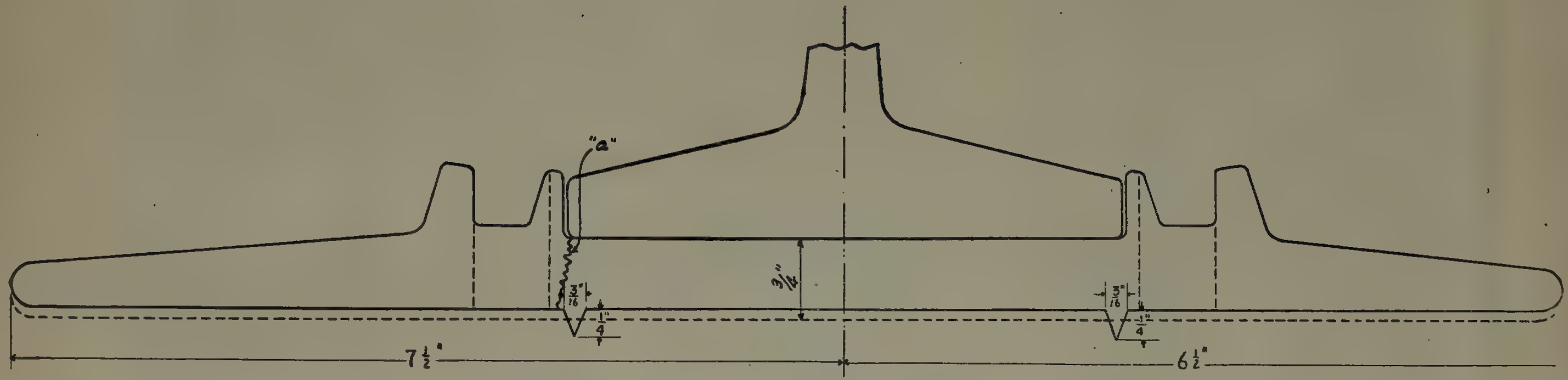
SECTION AT RAIL JOINT



SECTION AT INTERMEDIATE POINTS
Plate Inverted



New York Tunnels Tie-Plate.
Area=94.50 Sq. In.



STUDY OF TIE-PLATE WITH APPROXIMATELY 100 SQ. IN. AREA.

ten inches, the full width of the tie, and expect in so doing to double the life of these expensive ties.

The length of the proposed plate, 14 inches, is about the extreme dimension in this direction. If we find that more area than about one hundred square inches is necessary, we will have to provide it by extending the tie-plate in the other direction, and this may possibly be done, as said before, when we are able to get all ties for our main tracks with eight inches or more face. The reason the Committee recommended increasing the bearing surface of tie-plates was because in our screw-spike experiment, being conducted on the Middle Division east of Birmingham, in Type 7, which is the New York Tunnel tie-plate with 94.5 square inches bearing surface, the plates have cut into the creosoted red oak ties as much as half an inch, and into the creosoted pine ties as much as five-eighths of an inch in three years' service, and we considered one hundred square inches the most we could economically get from a tie-plate seven inches wide.

Yours truly,
(Signed) L. R. Zollinger,
Engineer Maintenance of Way.

Mr. S. C. Long,
General Manager.

May 6, 1913.

Dear Sir:—

The Screw-Spike Committee, appointed by the President several years ago, which is investigating the performance of several types of tie-plates, including the standard plate, and driven and screw-spikes, has under observance the stretches of track on Wooster Hill, on the Eastern Division of the P. F. W. & C. Ry., and east of Birmingham, on the Middle Division, Lines East. Inspections have been made semi-annually, and one was due in April, but on account of the floods on our Lines West, our western members of the Committee were unable to attend; therefore, the meeting was arranged for last week, but, unfortunately, Mr. Richards, the Chairman, and Messrs. Johnson and Cushing, of the Lines West, were unable to attend. There was present Mr. Trimble, Mr. Creighton and myself; we spent one day at Wooster and the next day at Birmingham.

On account of the volume of traffic at Birmingham being three times what it is at Wooster, the results at Birmingham are comparatively more striking, and while nearly all of the types of the experiments on the Wooster Hill are in pretty good shape, at the present time at Birmingham the weaknesses have developed in such a way that several types without doubt can be eliminated. There are three points at present that appear settled: First, that under our conditions the screw-spike is not satisfactory or economical; second, that a modification of the type of tie-plate which we used in the New York Tunnels will give the best satisfaction and is probably necessary on curves and on soft ties under heavy traffic; third, that the present tie-plate with a little greater bearing area will be satisfactory for tangents, especially on the branch railroads.

On account of but few members of the Committee being present at the last inspection, it was thought best to make no report at this time, and that certain changes be made in the experiment east of Birmingham, one of which is to insert cast-iron split linings to engage the screw-spikes which have worn so loose as to permit of their being drawn out by hand. We expect to have a full Committee meeting and go over the track at Birmingham the first week in June, when we may be able to make definite recommendation.

In addition to the experiments that are being carried on, we are developing a modification of the New York Tunnel tie-plate, which will lessen the number of screw-spikes, possibly cheapen the plate somewhat and give a better supporting shoulder on the outside of the rail. We propose to make a rather definite report in about a month.

Yours truly,
(Signed) L. R. ZOLLINGER,
Engineer Maintenance of Way.

Mr. S. C. Long, July 24, 1913.
General Manager.

Dear Sir:—

Under date of December 18, 1912, Mr. Rea, then Vice-President, wrote us a memorandum concerning the proper thickness for tie-plates of an approximate area of 100 square inches, and the question of using 20 ties per 33 ft. rail.

We attach a copy of this memorandum and beg to submit a brief report of our investigations along these lines, as follows:

In 1907 when the study of the track structure for the New York Tunnels was taken up, the area and thickness of the tie-plate was arrived at as follows:

The maximum weight per axle of the electric locomotives is 52,000 lbs. Oak wood being reasonably capable of sustaining a load of about 300 lbs. per square inch, it was determined that the area of the tie-plate should be approximately 95 square inches, and in order to arrive at the thickness, experiments were conducted on 18 plates 7 inches wide and 15 inches long, making 105 square inches in area; six of these plates being ½ inch thick, four ¾ inch, and six 1 inch.

Two plates of each thickness were sent to Altoona for laboratory tests and 4 of each were placed in one of our busiest tracks near Broad Street Station in June, 1907.

The Engineer of Tests made 164 observations in the Testing Laboratory, both for penetration and for stiffness, and while the results of the observations were somewhat indeterminate on account of the variation of the wood (although the wood was selected so that it would be as uniform as possible), the conclusion as to the thickness of the plate at ⅝ inch was pretty well determined. The attached Exhibit "A" will show the results of these tests. (pp. 100-109.)

On account of the rather indeterminate results the Test Department and ourselves agreed that more reliable conclusions could be drawn from the actual tests in track.

After observations of the 12 plates in track at Philadelphia for one year, there were no indications that even the thinnest plate was being strained beyond its elastic limit. Therefore the plates were removed and installed, in June, 1908, on No. 2 track near Pomeroy, which track carries our heaviest freight business at a pretty high speed. They were placed on three new ties, and three ties which had been in track from four to eight years. After observing these plates at this point six months, they were found to be in exactly the same condition as when first put in (with the exception that two of the small lag-screws, which secure the tie-plate to the tie, were loose in a tie that was pretty badly decayed). None of the plates showed any sign of bending or of cutting into the ties.

It may be noted in passing that when these plates were removed from track in July, 1912, after a service of over four years under our heavy freight traffic, the ¾ inch and 1 inch plates were not bent, and the ½ inch plates were bent only $\frac{1}{16}$ inch.

It was concluded from these tests and experiments that a plate ⅝ inch thick would be ample to protect the ties under such service as we would have at the New York Terminal, and the plates were accordingly designed 7 inches by 13½ inches by ⅝ inch thick.

After the plates were designed, but before they were installed, it was determined to make a further experiment with a large number of these plates under our heavy traffic, and accordingly 20,000 were ordered in March, 1909, and installed on the Middle and Pittsburgh Divisions. Some of these plates were installed on ties 8 inches thick, at Barree and Old Ferry on the Middle Division, and at Kittanning Point and Shafton on the Pittsburgh Division. On these 8 inch ties the principal thing we endeavored to determine was whether under our heavy eastbound passenger and freight traffic it would not be economical to use thicker ties, and at the same time to further consider the dimensions of the New York Tunnel tie-plates. More installations of this plate were made from time to time.

At the present time there are 119,000 plates in the two tunnels and in the station tracks at New York. On the New York Division 3840 plates, on the Philadelphia Terminal Division 1346 plates, on the Middle Division 19,594 plates, and on the Pittsburgh Division 2954 plates, so that we have 146,734 plates of the New York Tunnel type installed and in service, ranging from 1909 to the present time.

We have had in the last two months a large number of these plates tested with a steel straight edge in order to determine whether the traffic is straining them beyond their elastic limit, and whether it is necessary to make them thicker to withstand the present loads. It was found on the Manhattan Division upon examination of more than 1000 plates only one plate was bent as much as ⅛ inch. While there were some bent less than this amount, it was found on examination of 75 plates that had never been in track, that many of the plates coming from the mill showed a slight imperfection as to surface, one of them being bent ⅛ inch, and therefore it was determined that the slight distortion found in some of the plates had not been caused by the traffic. On the Pittsburgh Division at Shafton out of 210 plates examined, both on curves and on tangents, no plates were found bent. This track carries the westbound freight business, a large portion of which is loaded. On the Horse Shoe Curve about 1600 plates were examined on No. 3 track and none were bent. It must be borne in mind that this track carries our westbound empty freight business at a very low speed. On the Middle Division 100 plates were examined in No. 2 track west of Barree and none found bent, and at Old Ferry 100 plates were examined and none found bent.

In No. 4 westward freight track on the Rockville Bridge, 40 tie-plates were examined and none of them was found to be bent. Of 164 tie-plates from the eastward freight track at Covallen, Durward, Longfellow, Ardenheim and Huntingdon, all placed on chestnut ties in 1909 or early in 1910, 16, or 10 per cent., were found bent. All the bent plates were found under the low rail of curves.

On the New York Division 110 tie-plates were examined and none found bent sufficiently to warrant the belief that they had been distorted in service. One had a set of 3/32 inch and 3 others 1/32 inch.

This type of plate was installed also on the eastbound passenger track near 34th Street Bridge, West Phila., the tie-plates being underlaid with cow-hair pads, English style. In this track we inspected 100 plates and found no indication of bending, and very little tendency to cut into the ties or for the ties to split.

From these tests and from our experience in the New York Tunnel we are satisfied that the ⅝ inch plate is heavy enough for our passenger traffic, but perhaps not quite thick enough for the heavy freight traffic which we have in No. 2 track Middle Division, especially on the low side of curves.

In regard to the question concerning the calculated thickness of plates 14 inches long (100 square inches bearing surface) following the formula by Gustav Lindenthal, applicable to bridges, we would say that the formula embracing 300 per cent. of the load for impact might be correct for structure of a character where the failure of any particular member means the collapse of the entire structure. In the case of a tie-plate, however, the question of safety is not involved, for whether the tie-plate is strained beyond its elastic limit, or broken, the safety of the track structure is not impaired; furthermore, with the form of track structure now in use, the rail being a continuous beam, and roadway and tie being more or less yielding, the weight passing over the road being transmitted to the tie-plate and the tie and eventually to the roadbed are very much less than were the load transmitted directly to the tie-plate, tie and roadbed independent of the adjacent structure. However, using the ordinary formula for bending moment, and assuming that the base of rail distributed the load equally on the portion of the tie-plate with which it is in contact, and that the tie-plate is thick enough to distribute the load equally on the tie throughout its bearing area, taking the minimum wheel load at 35,000 lbs. and adding as much as 50 per cent. for impact (it being a question whether anything should be added for impact when the additional strength afforded by the continuous rail is considered) a tie-plate 7 inches wide and 14 inches long, assuming the allowable unit fiber stress 30,000 lbs., would figure roughly 1 inch thick.

The Joint Committee on Screw-Spike Test had a full meeting Thursday, June 26th, and, after having studied this problem for several years, observing the tests we are making on Wooster Hill on the Lines West, and at Birmingham on the Middle Division, and data given you, some of the members were of the opinion that ¾ inch would be ample and the others thought ⅞ inch the proper thickness.

Since this meeting we have received diagrams (attached marked "Exhibit B," pp. 110-120) of some tests with tie-plates made at Altoona in order to throw more light on this subject. The plates tested were as follows:

7 inch x 13½	inch x ⅝ inch	(New York Tunnel Design)
7½ inch x 14	inch x ¾ inch	(Plain Plates)
7½ inch x 14	inch x ⅞ inch	" "
7½ inch x 14	inch x 1 inch	" "

The diagrams show that the loads necessary to bend these plates when spiked to white oak ties that have been in service four years were as follows:

⅝ inch plate	60000 lbs.	Minimum
¾ inch "	90000 "	"
⅞ inch "	90000 "	"
1 inch "	110000 "	"

These tests show a ⅝ inch plate sufficient and confirm our experience in track.

As noted above, only 17 tie-plates 7 inch x 13½ inch x ⅝ inch were found bent as much as ⅛ inch out of about 3500 plates carefully measured with a steel straight edge after from one to four years' service, and all the bent plates were under the low rail on curve and on chestnut ties. Therefore it seems manifest that a tie-plate ¾ inch thick, which this test shows to have 50 per cent. more stiffness than the ⅝ inch plate, will be amply heavy to protect the tie under any traffic we can foresee at this time.

The following figures show that a tie-plate any thicker than ¾ inch would not be economical compared with the small standard tie-plate.

The average price for an untreated white oak cross-tie is 90 cts., 2 standard tie-plates and fastenings 38 cts., the cost of installation under our heavy Main Line traffic is 40 cts., making a total of $1.68, and its life is six years, which results in a cost per annum of 38 cts.

If we were to assume that the application of large tie-plates would increase the life of the tie to ten years, the amount of money we could afford to put into the tie-plates and fastenings would not exceed 80 cts. or 40 cts. per plate including fastenings, as this would also be equivalent to an annual expenditure of 38 cts.

Ten years may seem a short life for a tie adequately protected from mechanical destruction, but it must be borne in mind that the traffic we are considering is our heaviest and fastest business on stone ballasted track which is constantly being tamped, and after observations it is a question whether, with the best protection on the top of the tie with a plate such as we are describing would afford, the bottom of the tie would resist tamping more than ten years. A tie-plate costing not more than 40 cts. for both fastenings and plate would weigh approximately 21 lbs., which, distributed over 100 square inches, would result in a plate ¾ inch thick. Therefore, based on experience in the last five years with plates approximating 95 square inches of bearing surface, based on such calculations as we think applicable to the problem, and based on the economical side, a tie-plate should not be more than ¾ inch thick.

In regard to the experiments being conducted on the Lines East and West with tie-plates being made of two areas, the smaller one being practically 63 inches and the larger one approximately 93 inches. The cutting of the ties on the Lines West after three years of service is very slight, the oak ties showing practically no cutting—while on the pine ties it is just noticeable. At Birmingham on the Middle Division, Lines East, where the eastbound passenger and freight business is concentrated on the experimental track, the cutting in the ties is quite marked. The various tests are conducted on both tangents and 6° curves, and, while there is very little cutting on the tangents, the tie-plates on the low sides of the curves (especially the small tie-plates) have cut in more than ½ inch. The large tie-plates have cut in from ¼ inch to ½ inch. On the high sides of these curves there is some cutting, but it is not very noticeable.

On those ties where the large plate is firmly joined to the tie by four spikes, so that there is practically no movement between the tie-plates and the ties the cutting is not as great as where the tie-plate has not been rigidly fastened to the tie, so that the cutting cannot be attributed to the crushing under the weight, but rather to the wear and abrasion of the tie due to the movement of the plate. By fastening the plate to the tie more rigidly this abrasion or cutting can be materially reduced.

The 100 square inches for the tie-plate as determined by K-29 Committee and as determined by our figures and observations, is the maximum that can be economically considered, unless the cost of cross-ties is very much increased in the next five years. While our experiments at Birmingham and Wooster have been made with creosoted ties, we do not consider that creosoted mixed oaks, birches, beeches and maples would be as economical in our Main Tracks on stone ballast, as a white oak tie, for the reason that whether creosoted or not, the abrasion of the under side of the tie due to tamping of the ballast will not permit of a life of an untreated white oak tie longer than its decay period, and would not permit of the life of a creosoted tie more than half of its decay period. Our treated ties are being located on parts of the road where we expect, with tie-plates protection, they will give us from sixteen to twenty-four years' life. White oak, which is untreatable and the hardest and best wood we know of, being available in considerable quantities (and will probably be available in sufficient quantities for the heaviest part of our Main Line traffic for some time to come) we are not in the position of being forced to inferior woods for our heaviest business.

In regard to the use of 20 ties to a 33 ft. rail, comment is made that ties placed so close together as this rule necessitates, the tamping cannot be properly done. In defence of this practice we would state that the following roads have used 18 ties to a 30-ft. rail, or 20 ties to a 33-ft. rail length for some years: Denver & Rio Grande; Chicago, Burlington & Quincy; Chicago, Rock Island & Pacific; St. Louis & San Francisco; Grand Trunk; Missouri, Kansas & Texas; Colorado & Southern; Maine Central; Chicago & Eastern Illinois; Chicago, Indianapolis & Louisville; El Paso & Southwestern; St. Louis, Brownsville & Mexico; Michigan Central.

Our Lines West adopted this as its standard last year, after having tested track so constructed, covering a period of a year. Their Foremen and Supervisors state that it is not difficult to tamp ties so spaced, and this is borne out by our experience. For 20 years at least the distance between the bearing surfaces of joint ties on the Lines East has been 11 inches or less, and we have never had a complaint that the gangs were not able to tamp these ties properly. With 20 ties to a 33-ft. rail length, the joint ties being spaced standard, or 11 inches between bearing surfaces, and the ties averaging 8 inches face, the distance between bearing surface of all ties except joint ties is 12 inches. This question was discussed at the meeting last week, and the Committee was unanimous in endorsing the rule that 20 ties be applied under a 33-ft. rail.

We attach hereto the three blueprints which accompanied the memorandum of December 13, 1912. and have modified print No. 3 to show a thickness of ¾ inch instead of ⅝ inch, p. 93.

Yours truly,

(Signed) L. R. Zollinger,
Engineer Maintenance of Way.

Memorandum referred to in previous letter:

As the width of a tie-plate under the rail is limited by the width of the tie, the bearing area must be obtained by greater length of tie-plate in the way that Mr. Zollinger shows on sketch 3, p. 93. Will the proposed thickness of ⅝ of an inch be sufficient for distributing the load from the rail over the proposed length of tie-plate of 14 inches?

If we assume a wheel pressure of 30.000 lbs. upon the tie-plate, then the pressure per square inch would be 300 lbs. on the wooden tie. With that pressure, however, there would be no cutting into the tie: that should only occur when the pressure exceeded 900 lbs. As Mr. Zollinger states in his letter that the tie-plates cut into red oak as much as ½ of an inch and into creosoted pine ties as much as ⅝ of an inch in three years' service, it would indicate that the pressure upon the tie-plates is much more than 300 lbs. per square inch. and that it probably is nearer 900 to 1000 lbs. per square inch. This latter pressure would coincide with the deductions in "A New Impact Formula" recently issued. where the author, Gustav Lindenthal, who is Chief Engineer of the East River Bridge Division, New York Connecting Railroad. assumed the effect of the impact to be equal to three times the quiescent pressure.

Starting out from this fact. as confirmed in Mr. Zollinger's letter. the tie-plates 7 inches wide and 14 inches long. which he proposes, would need to be about 1¾ inches thick, so that the fiber stress at "a" (marked in red in blueprint 3, p. 93) should not exceed 20,000 lbs. per square inch. From this I judge that the tie-plates 14 inches long will bend down and crush into the wood, and possibly break if they are only to be ⅝ of an inch thick. Experiments made with these tie-plates will probably show this conclusively.

Can the expectation of 20 ties to 33-ft. rail be realized with good results, because of the difficulty of tamping the ties, unless they would be smaller in width than 8 inches? One would think that 18 ties, not less than 8 inches wide, per 33-ft. rail, are probably the maximum that can be counted upon as good practice; but from the facts above quoted from Mr. Zollinger about the tie-plates cutting into the ties, it appears necessary to provide tie-plates not only with a bearing area of at least 100 square inches, but also of such form and strength as to distribute the pressure from the rail evenly upon the tie. None of the tie-plates shown on the three blueprints herewith attached seem to have suitable form for that purpose.

December 18, 1912.

Altoona, Pa., July 24, 1907.

Subject: Tie-Plates.

Mr. A. W. Gibbs,
General Superintendent Motive Power.

Dear Sir:

Referring to your memorandum of June 14th, desk 2, with the attached letter of June 13th from Mr. J. T. Richards, Chief Engineer Maintenance of Way, asking to have certain tests made with tie-plates ½ inch thick, ¾ inch thick and 1 inch thick: I beg to say that these have been completed and the accompanying tables and plots show the information obtained in detail.

Tests were made by taking blocks of yellow pine 40 inches long, 10 inches wide and 7 inches thick. The tie-plate was placed on the center of each of these blocks, and the two series of tests may be divided generally and are so designated on the tables as (A) "Tests of tie-plates without screw-spikes" and (B) "Tests of tie-plates with screw-spikes."

In the series (A) none of the screw-spikes was used either for holding down the rail or securing the tie-plate to the tie.

In series (B) the screw-spikes were used both to hold down the rail and to secure the tie-plate to the tie; in the latter case four spikes being used for each tie-plate.

The block, plate and section of 100-lb. rail, was placed in the testing machine and subjected to compression, measurements of bending, sets and imbedding of the plate being observed. Zero was taken as 2000 lbs. and increments of 5000 lbs. applied until the plate had imbedded deeply, the tie split or the plate had bent out of shape.

The following table is a summary of the results compiled from the detailed tables:

	Tie-Plate with Screw-Spikes			Tie-Plate without Screw-Spikes		
	½″	¾″	1″	½″	¾″	1″
First bending of plates,	25,000 lbs.	30,000 lbs.	30,000 lbs.	30,000 lbs.	25,000 lbs.	20,000 lbs.
Corresponding set,	.010″	.005″	.002″	.012″	.002″	.005″
Load to imbed ⅛″,	60,000 lbs.	95,000 lbs.	80,000 lbs.	55,000 lbs.	85,000 lbs.	90,000 lbs.
Load to imbed ¼″,	85,000 lbs.	115,000 lbs.	95,000 lbs.	70,000 lbs.	105,000 lbs.	110,000 lbs.
Load to imbed ½″,	....	135,000 lbs.	120,000 lbs.	105,000 lbs.	125,000 lbs.	140,000 lbs.

The item in the first column designated as "Corresponding set" refers to the amount of set occurring with the load designated immediately above it.

In the figures opposite "Load to imbed" are given the loads which were applied when the amount of deflection of the plate was ⅛ inch, ¼ inch and ½ inch; in other words this is the deflection of the plate before the load was released.

It would seem from the above that the ¾ inch tie-plate, when used with screw-spikes, has the least bending under different loads. Further, it has also the greatest resistance to imbedding.

From these tests we would conclude that the ½ inch tie-plate was a little too thin to distribute the load applied on the rail, and that the 1 inch tie-plate was unnecessarily thick because it transmits practically all of the load without bending.

Mr. Richards will appreciate, of course, that these figures and conclusions are only from laboratory experiments and we do not think that necessarily the same conclusions in regard to thickness of plate would follow under road conditions.

Our recommendations, therefore, to conclude the matter would be that the ½ inch, ¾ inch and 1 inch tie-plates be used experimentally, taking sufficient track to show the effect. The breaking down of fibers of the tie in service is somewhat different than the crushing of the fibers in the testing machine.

Yours respectfully,
(Signed) E. D. Nelson,
Engineer of Tests.

Test Department
Altoona, Pa.
July 19th, 1907.

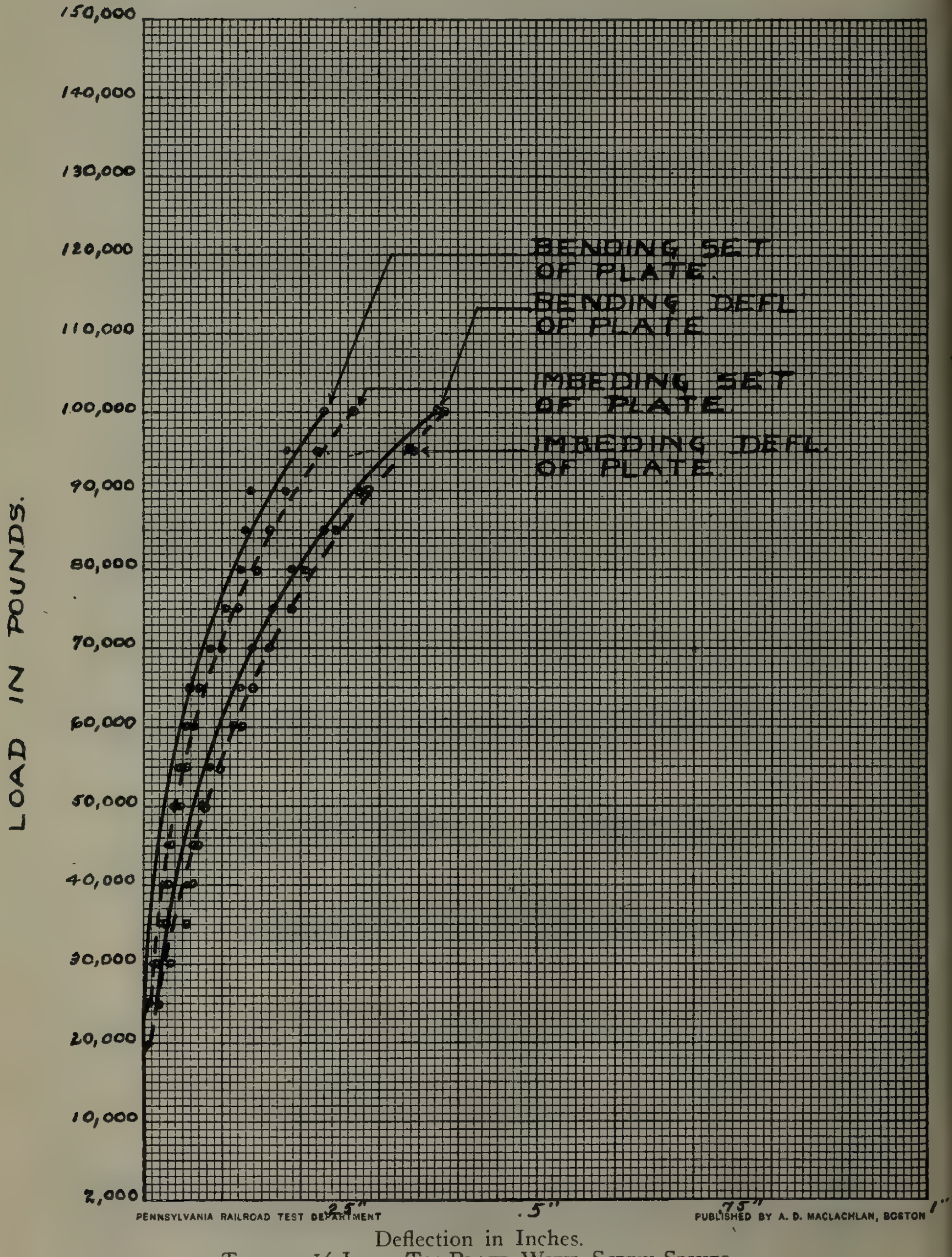
TABLE (A)
TEST OF TIE-PLATES WITHOUT SCREW-SPIKES.

Load Applied	½" Tie-Plate				¾" Tie-Plate				1" Tie-Plate			
	Bending		Imbedding		Bending		Imbedding		Bending		Imbedding	
	Deflection	Set	Deflection	Set	Deflection	Set	Deflection	Set	Deflection	Set	Deflection	Set
2000	.000"	.000"	.000"	.000"	.000"	.000"	.000"	.000"	.000"	.000"	.000"	.000"
5000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
10000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
15000	.007	.000	.010	.000	.000	.000	.000	.000	.000	.000	.000	.000
20000	.015	.000	.015	.005	.005	.000	.005	.000	.015	.005	.015	.005
25000	.020	.000	.020	.005	.005	.002	.010	.000	.025	.005	.025	.005
30000	.030	.012	.030	.015	.007	.002	.010	.000	.022	.005	.030	.005
35000	.035	.025	.040	.025	.007	.002	.015	.005	.022	.005	.030	.005
40000	.042	.027	.055	.035	.010	.000	.020	.005	.022	.007	.040	.015
45000	.060	.047	.065	.050	.005	.002	.020	.005	.022	.007	.040	.015
50000	.075	.057	.085	.060	.017	.002	.035	.005	.020	.007	.045	.015
55000	.117	.067	.130	.090	.027	.002	.040	.010	.025	.007	.05	.015
60000	.165	.087	.185	.115	.025	.000	.045	.020	.012	.007	.055	.015
65000	.197	.100	.215	.130	.045	.015	.065	.025	.030	.007	.065	.025
70000	.22	.130	.240	.155	.045	.017	.065	.025	.035	.007	.070	.025
75000	.252	.135	.275	.180	.062	.040	.085	.050	.045	.012	.080	.030
80000	.287	.145	.305	.195	.085	.040	.105	.055	.057	.005	.100	.030
85000	.315	.147	.335	.210	.100	.050	.125	.065	.057	.005	.110	.040
90000	.367	.165	.385	.245	.115	.070	.145	.080	.060	.007	.120	.050
95000	.415	.180	.430	.270	.145	.092	.175	.105	.072	.022	.150	.070
100000	.461	.195	.480	.305	.175	.105	.215	.120	.095	.037	.190	.100
105000	.505	.205	.505	.325	.210	.142	.260	.155	.100	.052	.225	.125
110000	.567	.230	.570	.365	.230	.160	.290	.175	.117	.057	.255	.140
115000	.605	.300	.630	.420	.270	.187	.350	.195	.122	.065	.285	.165
120000	.687	.340	.725	.475	.330	.225	.400	.25	.142	.075	.315	.185
125000					.347	.252	.460	.285	.162	.087	.355	.210
130000					.415	.307	.555	.325	.190	.110	.400	.250
135000					.465	.355	.620	.390	.200	.112	.440	.280
140000					.507	.400	.700	.445	.220	.132	.490	.310
145000					.59	.475	.820	.525	.220	.155	.530	.33
150000									.235	.142	.590	.365
155000									.260	.155	.675	.415
160000									.267	.197	.865	.565

Test Department
Altoona, Pa.,
July 19th, 1907.

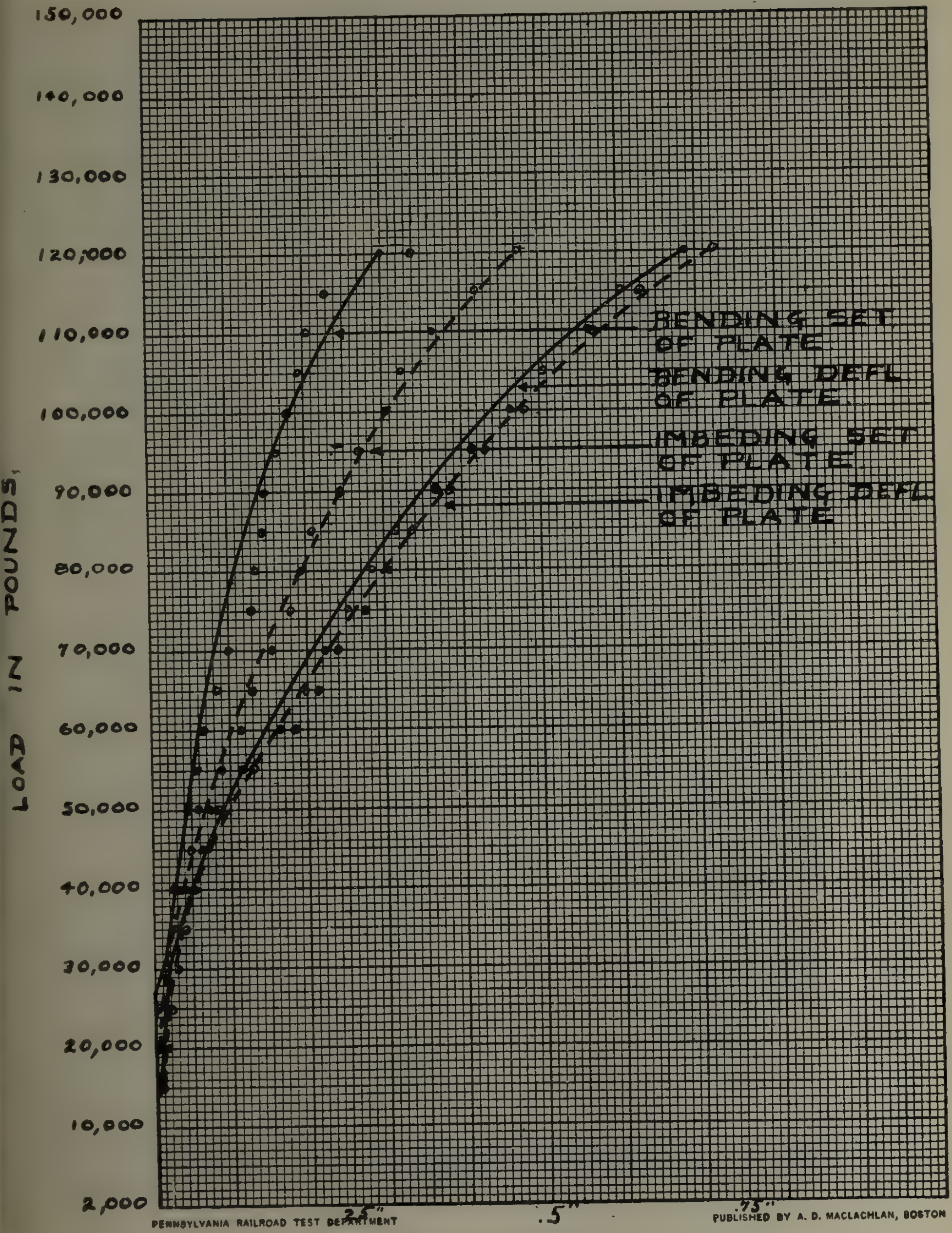
TABLE (B)
TEST OF TIE-PLATES WITH SCREW-SPIKES.

Load Applied	½″ Tie-Plate				¾″ Tie-Plate				1″ Tie-Plate			
	Bending		Imbedding		Bending		Imbedding		Bending		Imbedding	
	Deflection	Set	Deflection	Set	Deflection	Set	Deflection	Set	Deflection	Set	Deflection	Set
2000	.000″	.000″	.000″	.000″	.000″	.000″	.000″	.000″	.000″	.000″	.000″	.000″
5000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
10000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
15000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
20000	.010	.000	.010	.000	.005	.000	.005	.000	.005	.000	.005	.000
25000	.020	.010	.020	.010	.015	.000	.020	.000	.010	.000	.010	.000
30000	.035	.020	.035	.020	.025	.005	.030	.010	.017	.002	.020	.005
35000	.055	.030	.055	.030	.022	.015	.030	.015	.012	.002	.025	.010
40000	.057	.030	.065	.030	.025	.020	.030	.020	.022	.005	.030	.010
45000	.067	.035	.070	.035	.025	.020	.030	.020	.022	.000	.035	.010
50000	.075	.040	.080	.045	.032	.012	.035	.020	.027	.010	.040	.020
55000	.085	.045	.100	.055	.045	.015	.045	.020	.030	.007	.045	.020
60000	.112	.055	.125	.065	.042	.015	.045	.020	.035	.012	.050	.025
65000	.122	.06	.140	.070	.042	.020	.060	.020	.035	.012	.060	.030
70000	.137	.085	.160	.100	.057	.022	.065	.030	.045	.020	.070	.040
75000	.165	.105	.190	.120	.060	.032	.075	.040	.075	.022	.105	.050
80000	.190	.125	.205	.145	.070	.035	.085	.040	.082	.042	.130	.075
85000	.230	.130	.245	.160	.085	.037	.095	.045	.100	.057	.160	.095
90000	.272	.137	.285	.180	.095	.042	.110	.050	.112	.070	.200	.125
95000	.342	.182	.345	.220	.112	.047	.135	.055	.135	.105	.245	.165
100000	.375	.230	.38	.265	.117	.055	.150	.065	.140	.105	.285	.195
105000					.147	.075	.180	.085	.147	.127	.315	.225
110000					.175	.100	.215	.110	.167	.127	.360	.250
115000					.210	.117	.255	.130	.227	.142	.440	.270
120000					.305	.150	.345	.165	.207	.185	.475	.340
125001					.307	.185	.375	.190	.257	.227	.535	.395
130000					.355	.232	.420	.235				
135000					.442	.247	.490	.275				



Test of ½-Inch Tie-Plate With Screw-Spikes.

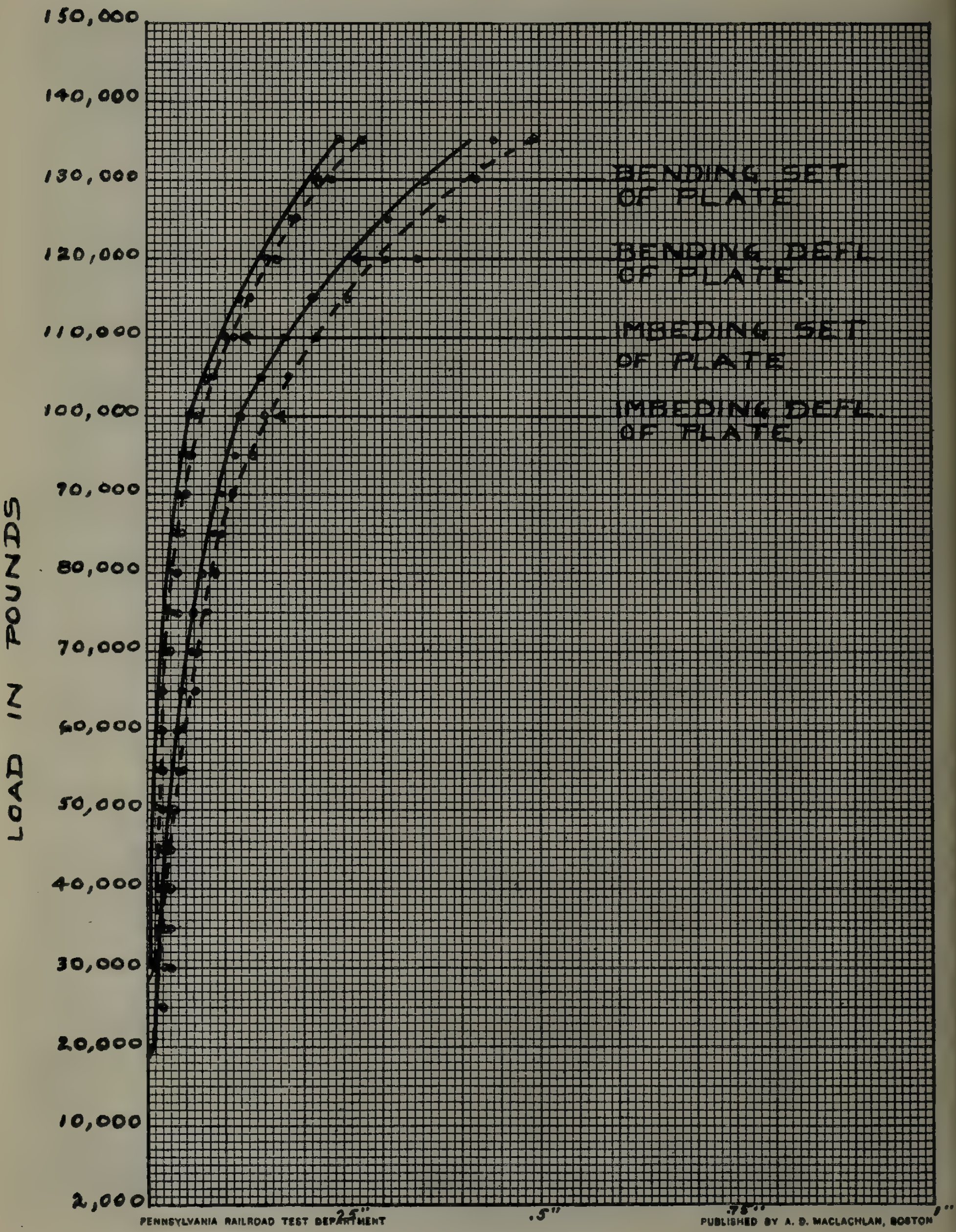
July 17, 1907.



Deflection in Inches.

TEST OF ½-INCH TIE-PLATE WITHOUT SCREW-SPIKES.

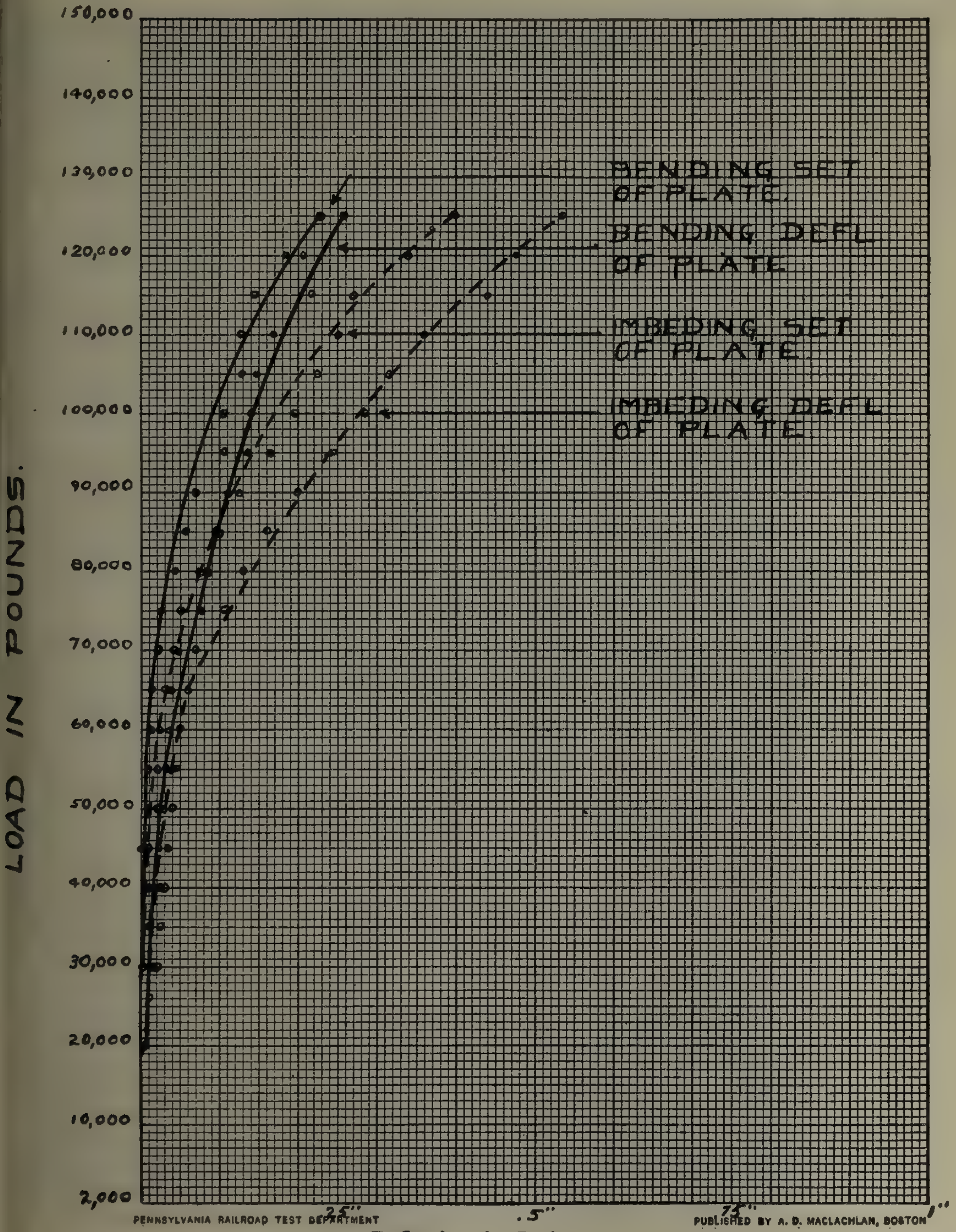
July 17, 1907.



Deflection in Inches.

Test of ¾-Inch Tie-Plate With Screw-Spikes.

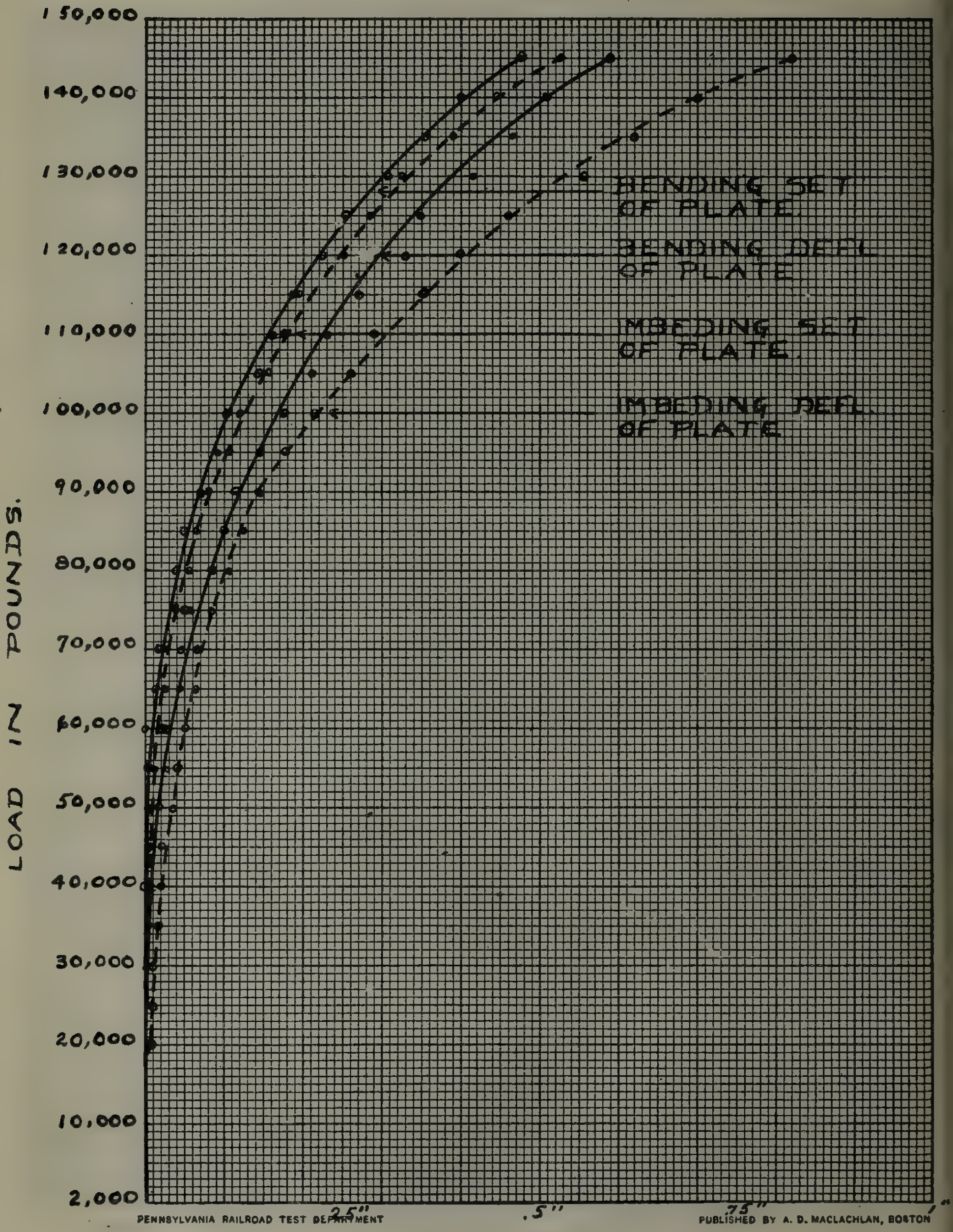
July 16, 1907.



Deflection in Inches.

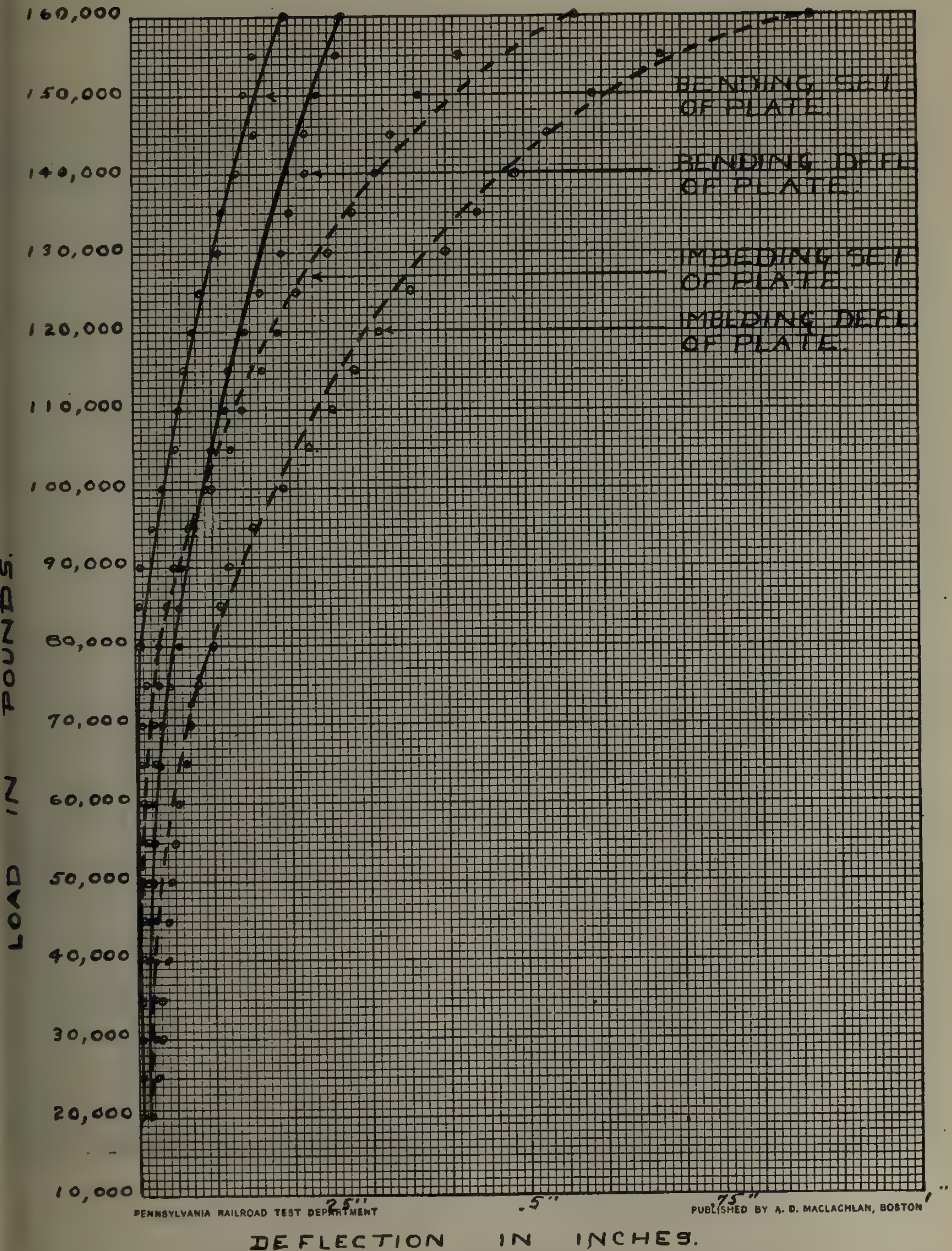
TEST OF ¾-INCH TIE-PLATE WITHOUT SCREW-SPIKES.

July 16, 1907.



Deflection in Inches.
TEST OF 1-INCH TIE-PLATE WITH SCREW-SPIKES.

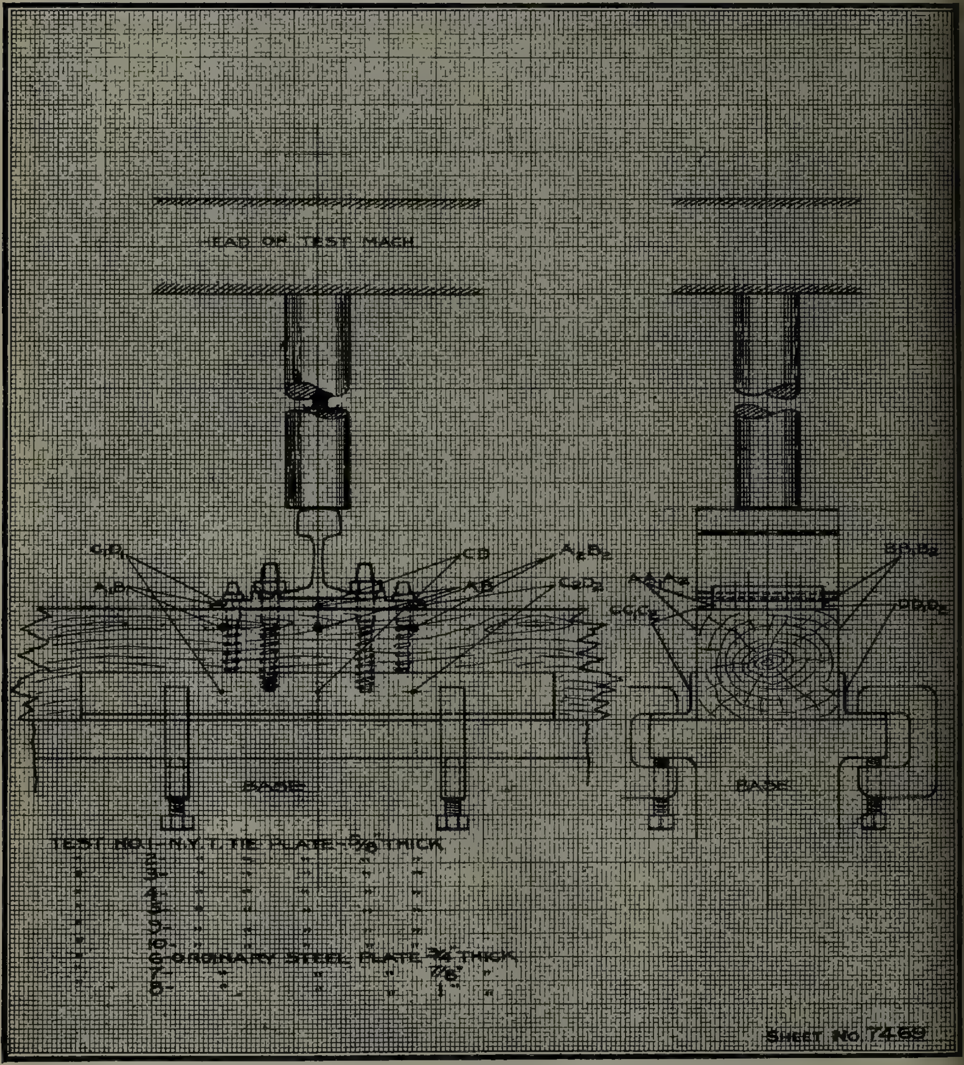
July 16, 1907.



Test of 1-Inch Tie-Plate Without Screw-Spikes.

July 16, 1907.

Report No. 13-131.



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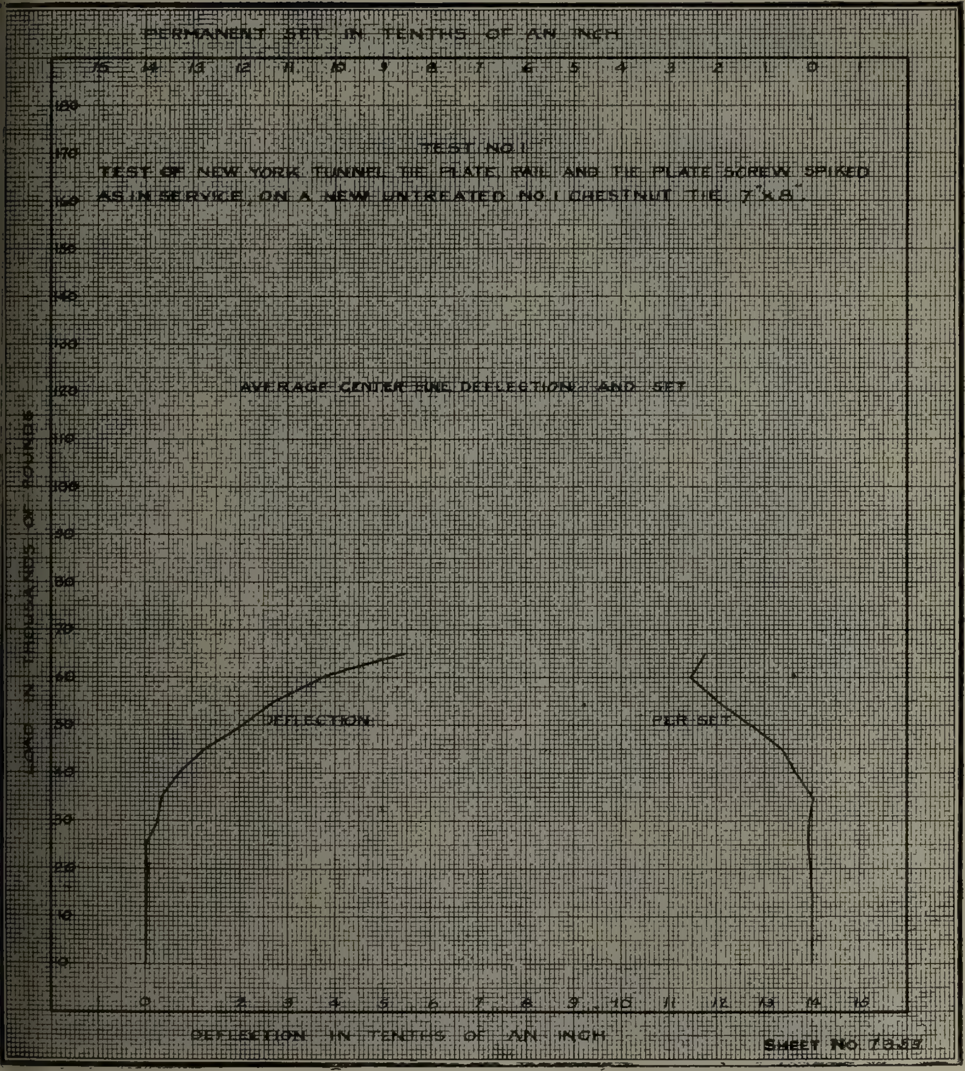

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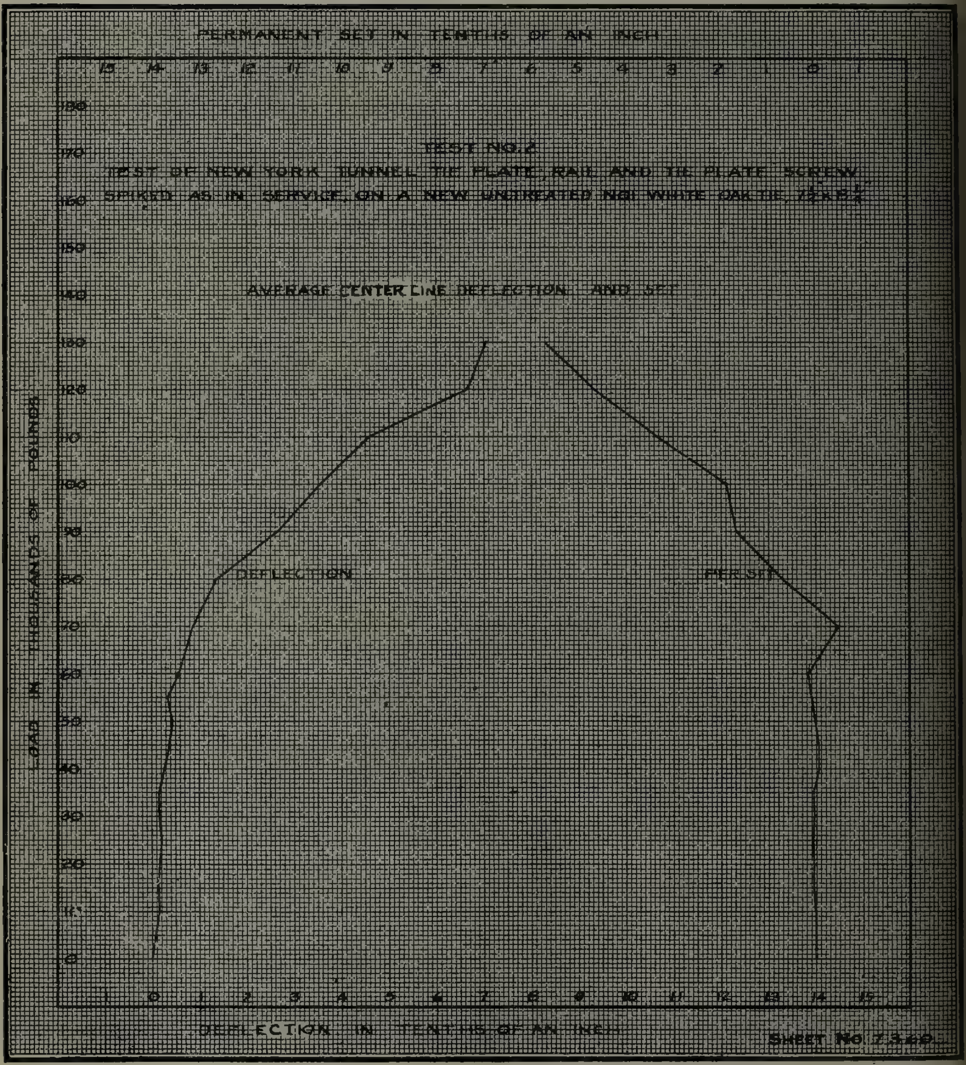

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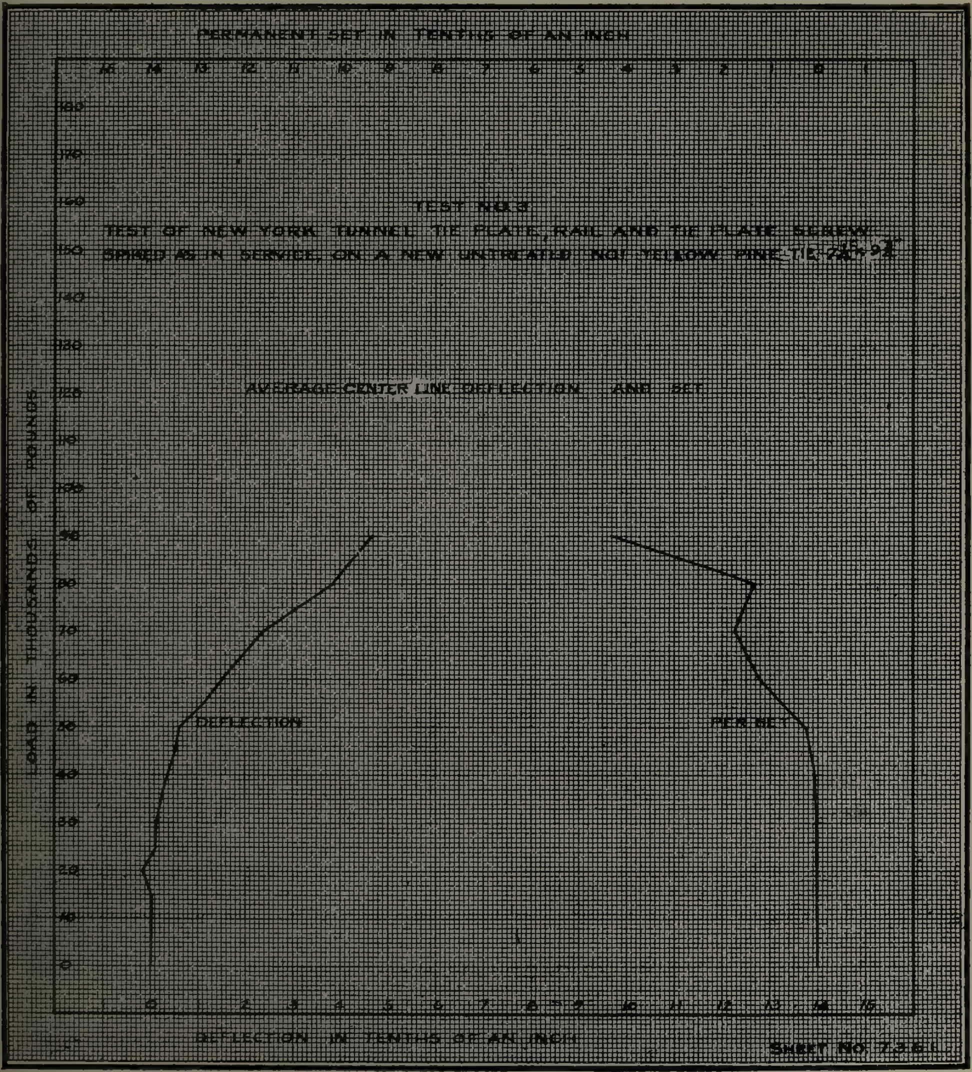

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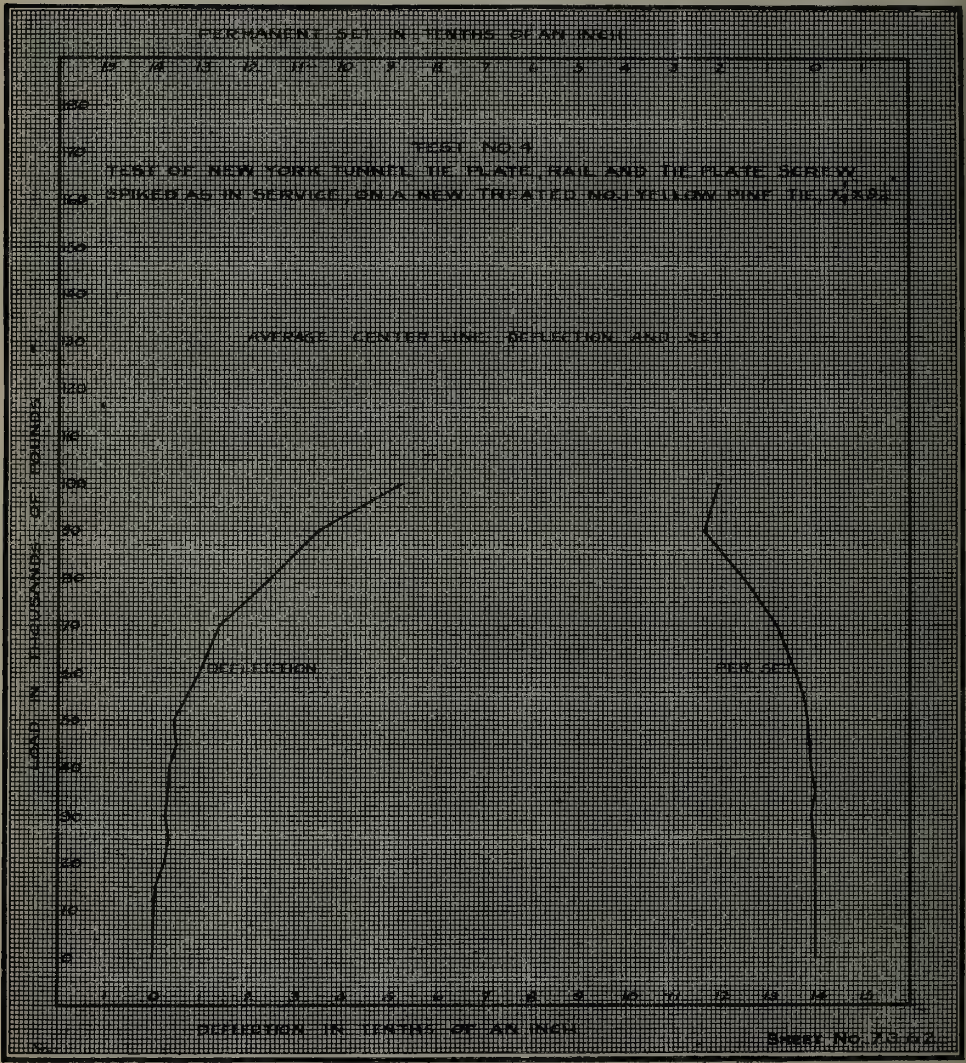

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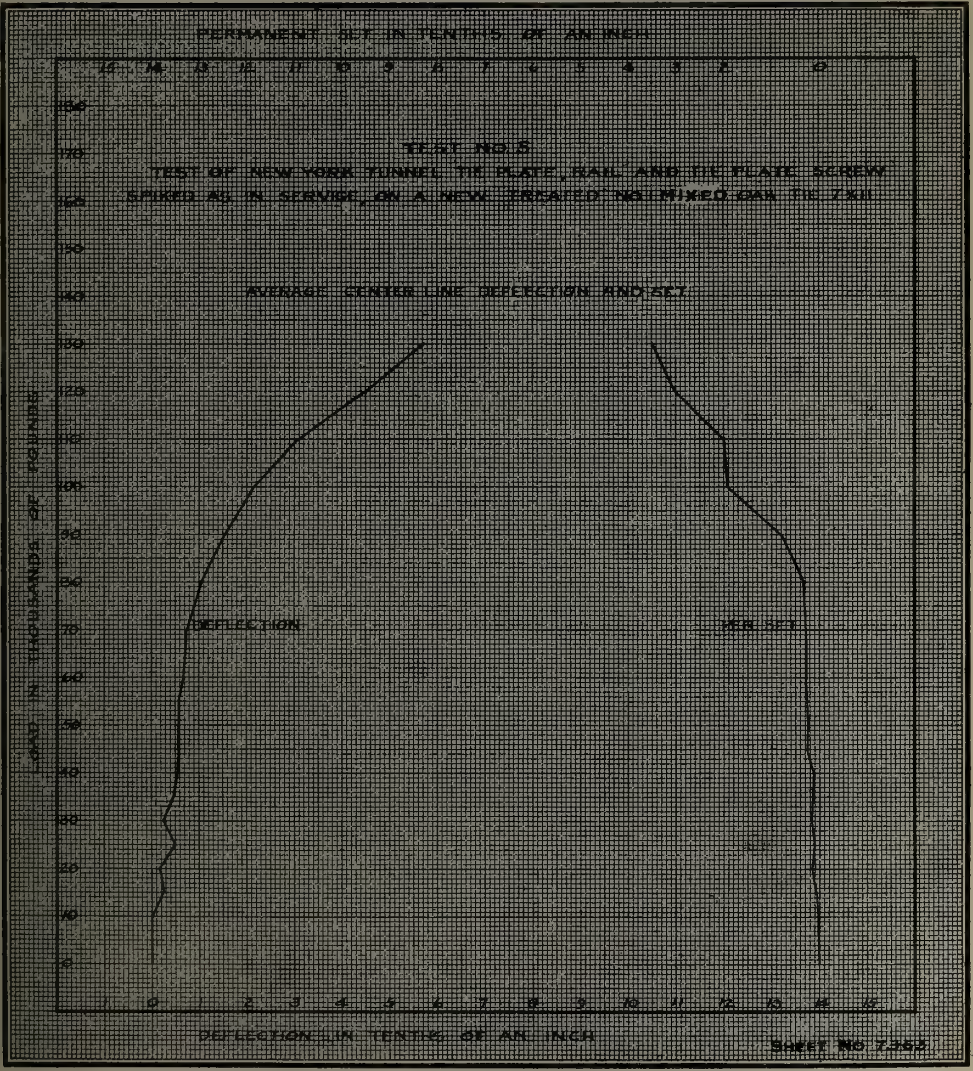

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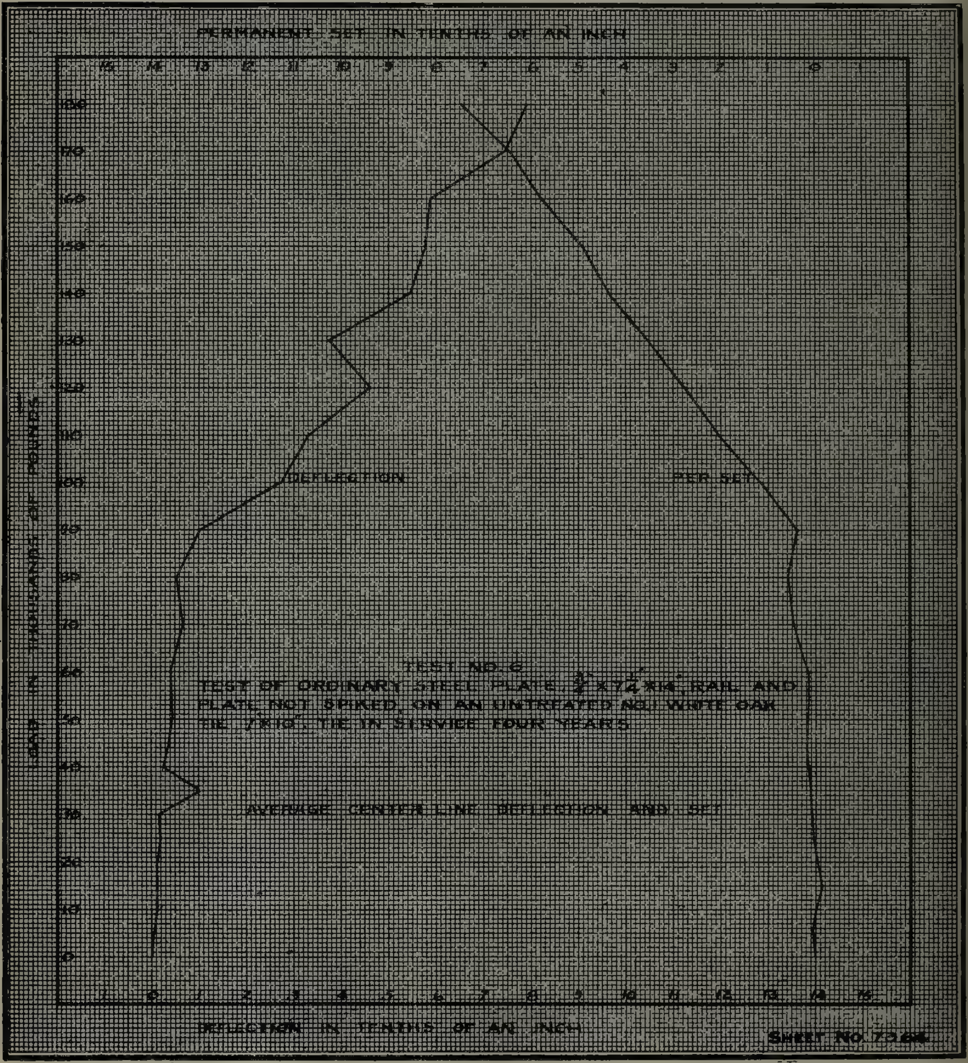


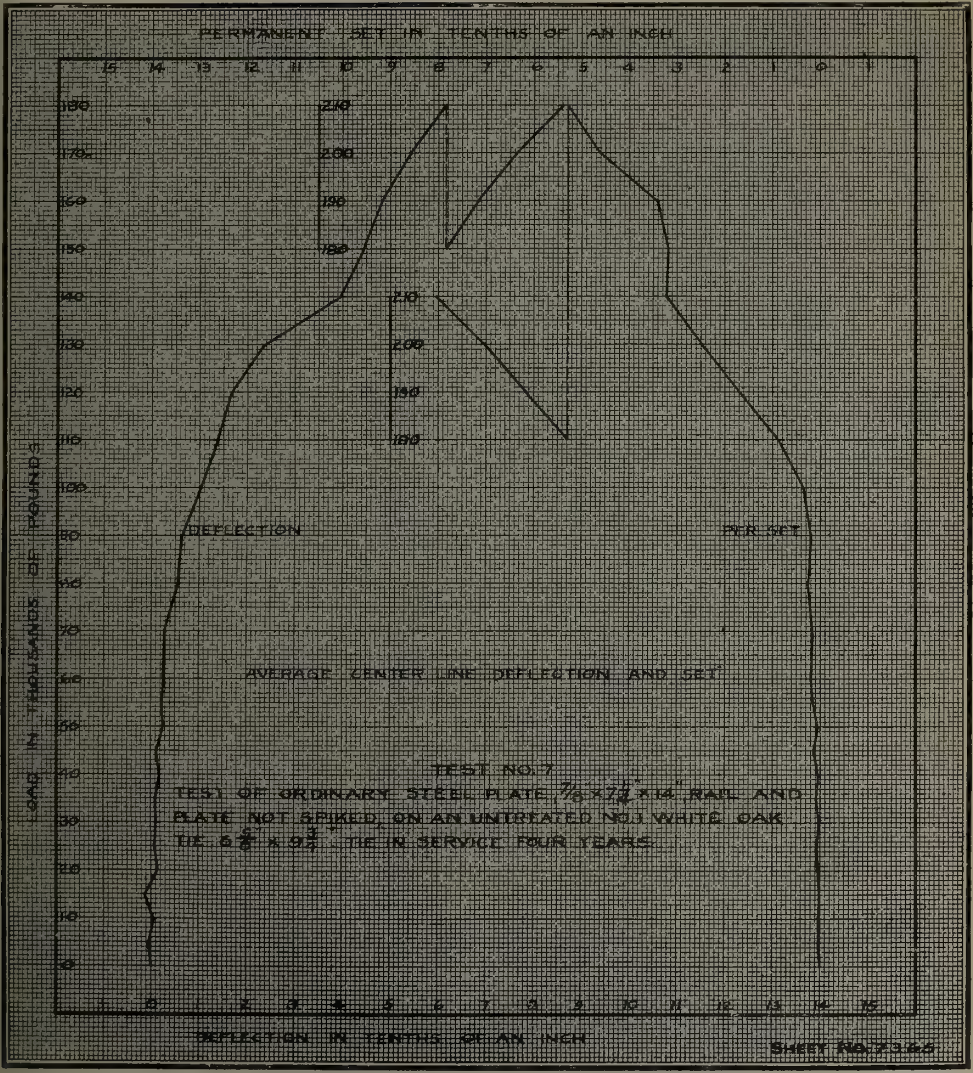
TEST NO. 6

TEST OF ORDINARY STEEL PLATE, ¾"X7¼"X14", RAIL AND PLATE NOT SPIKED, ON AN UNTREATED NO. 1 WHITE OAK TIE 7"X10", TIE IN SERVICE FOUR YEARS

AVERAGE CENTER LINE DEFLECTION AND SET

SHEET No. 7364

Report No. 13-131.

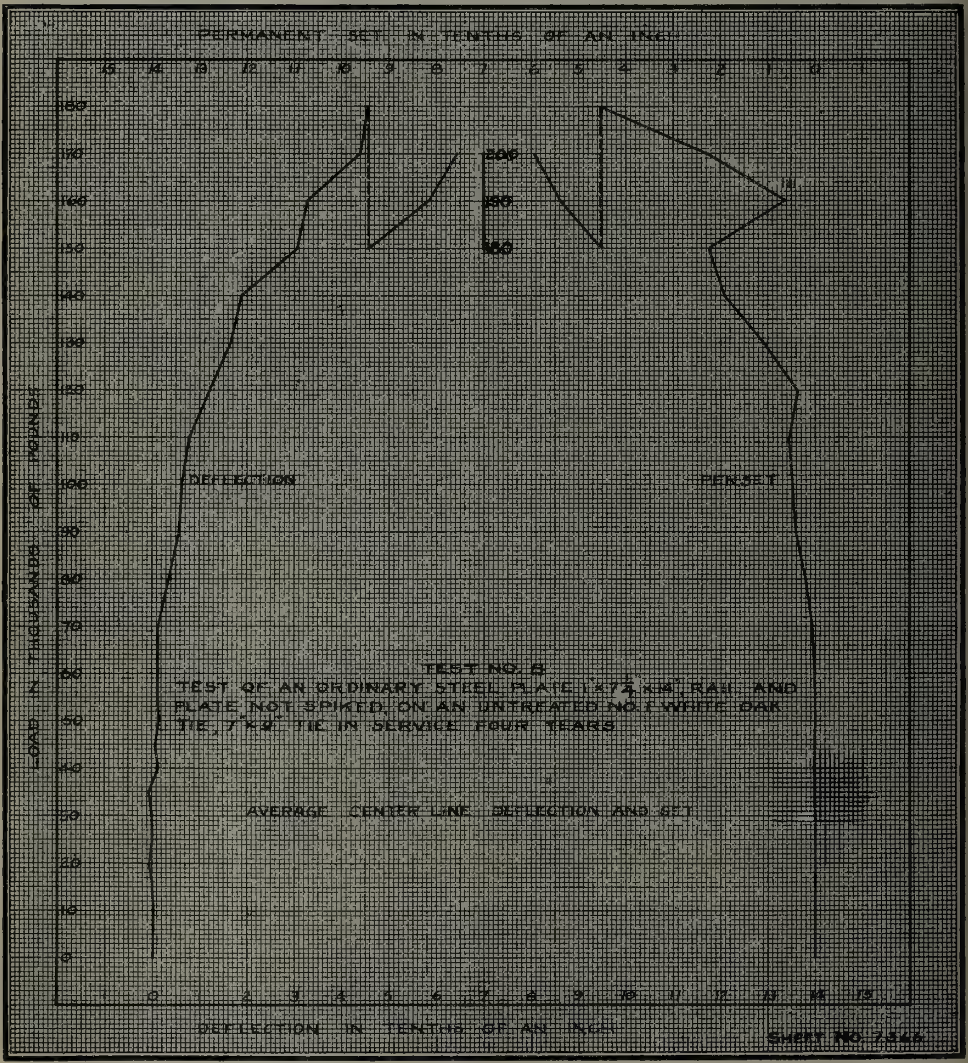


AVERAGE CENTER LINE DEFLECTION AND SET

TEST NO. 7

TEST OF ORDINARY STEEL PLATE $\frac{7}{8}'' \times 7\frac{3}{4}'' \times 14''$, RAIL AND PLATE NOT SPIKED, ON AN UNTREATED NO. 1 WHITE OAK TIE $6\frac{5}{8}'' \times 9\frac{3}{4}''$. TIE IN SERVICE FOUR YEARS.

Report No. 13-131.



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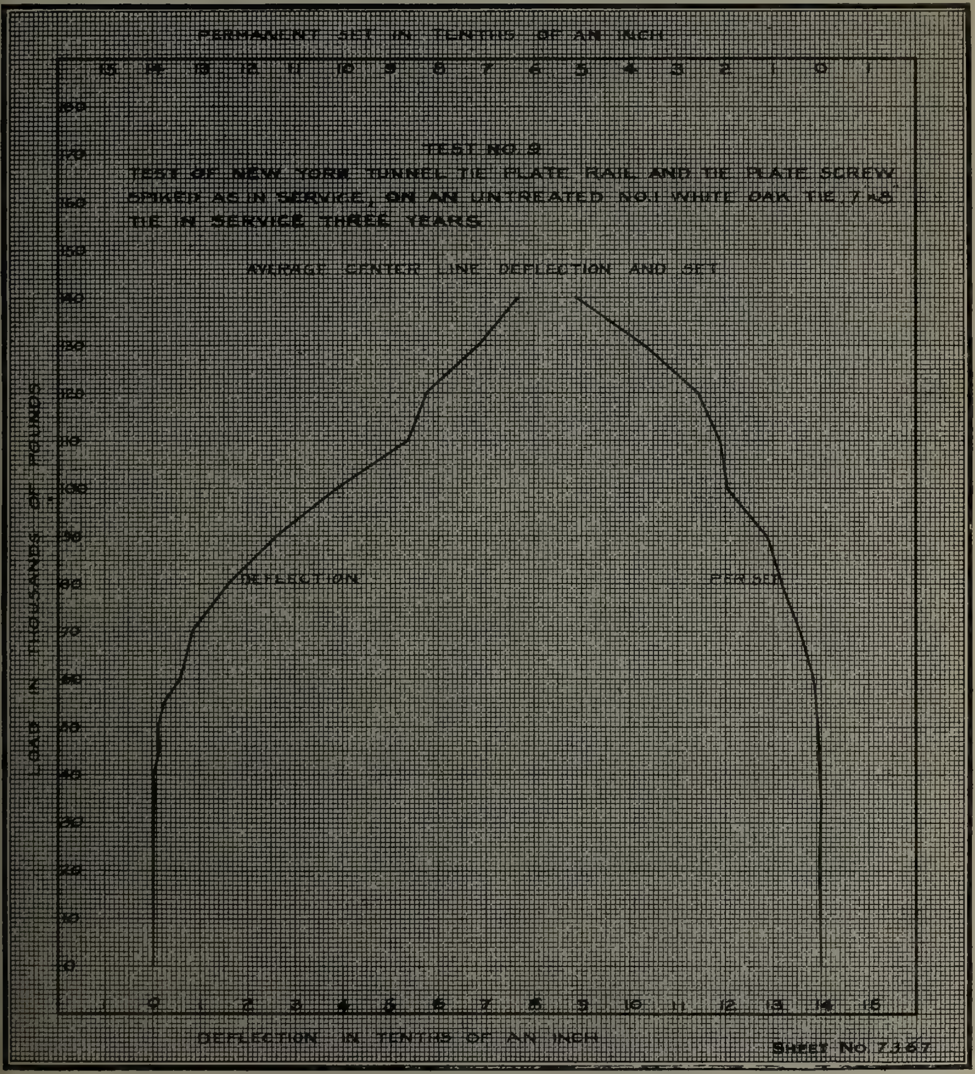

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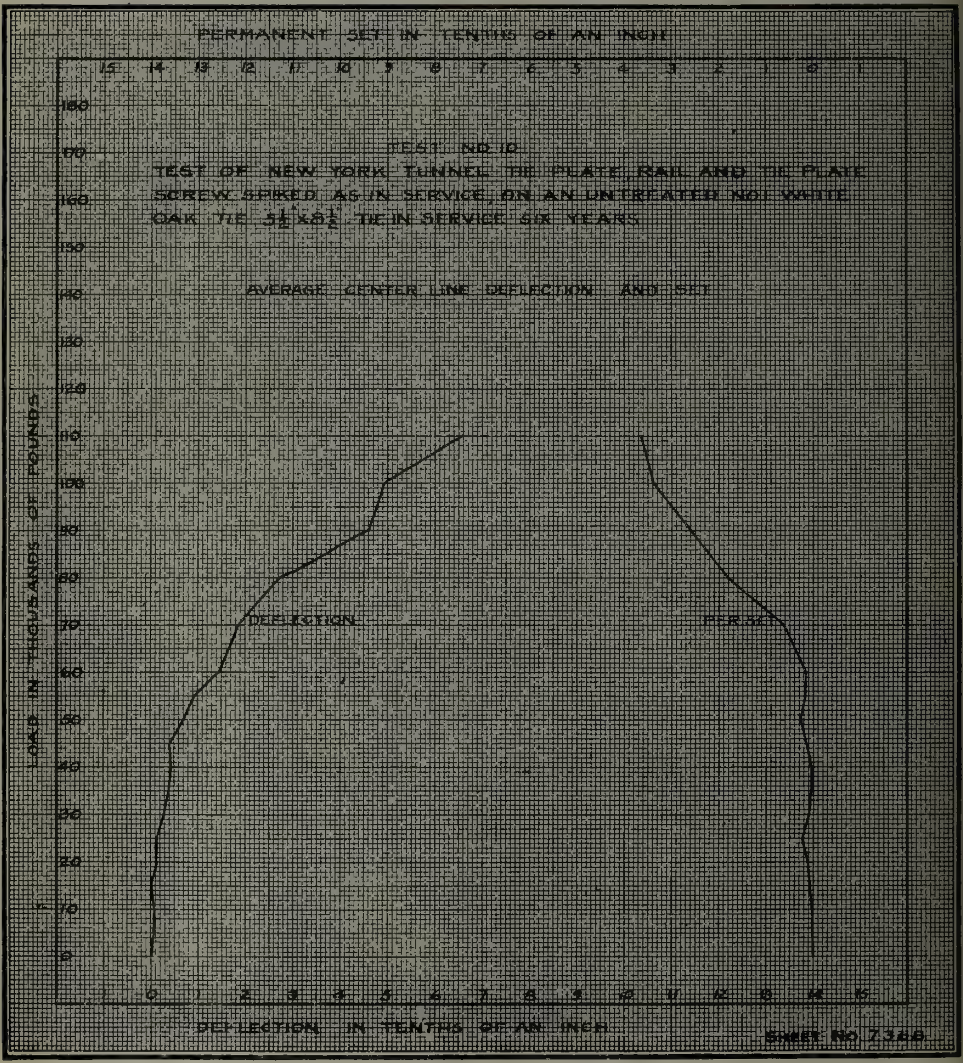
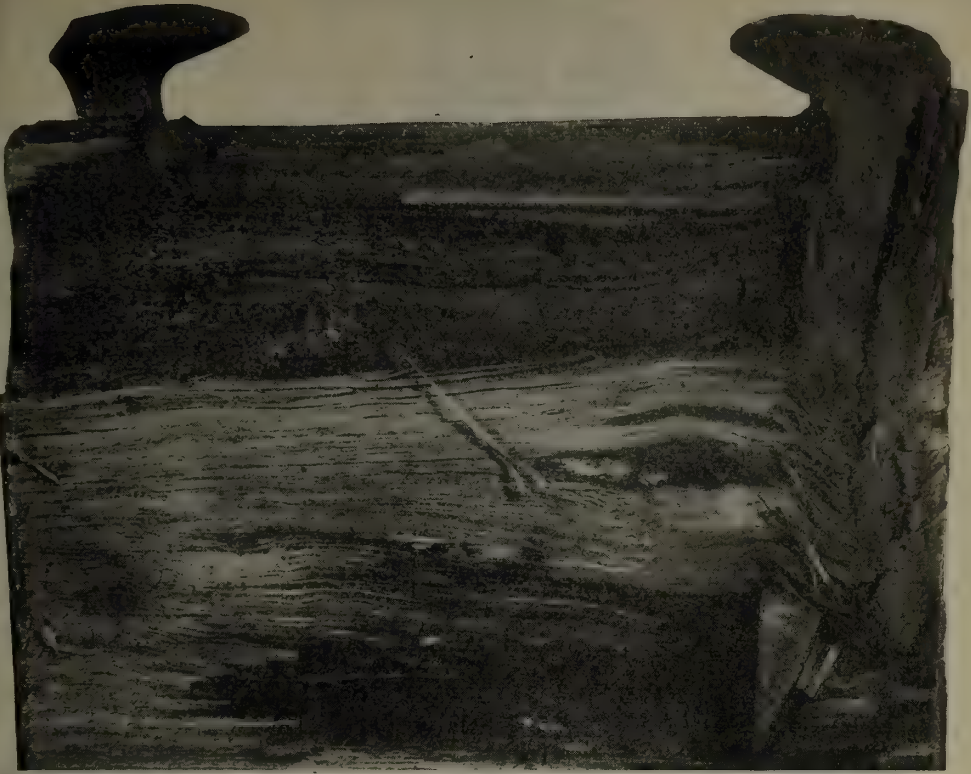
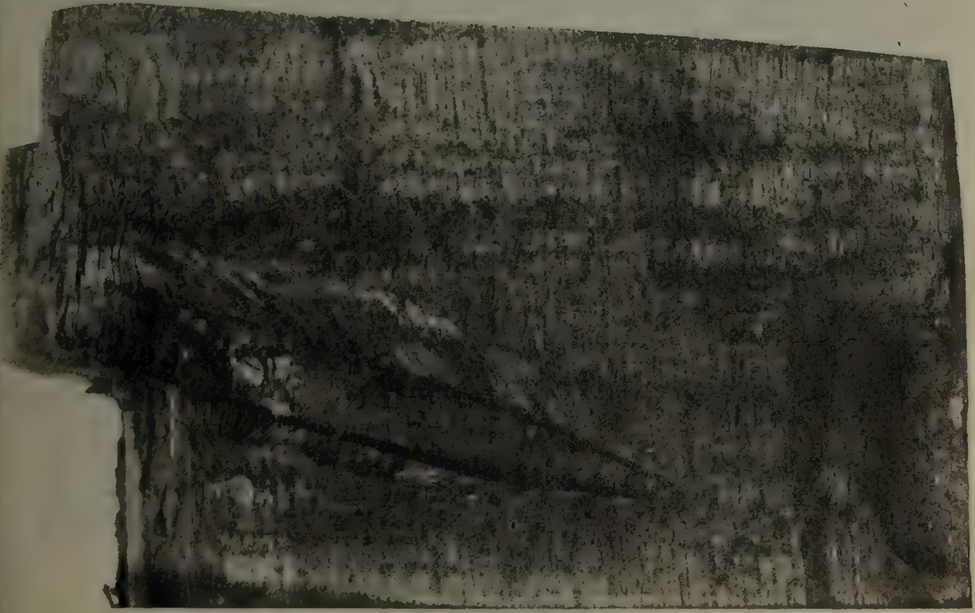


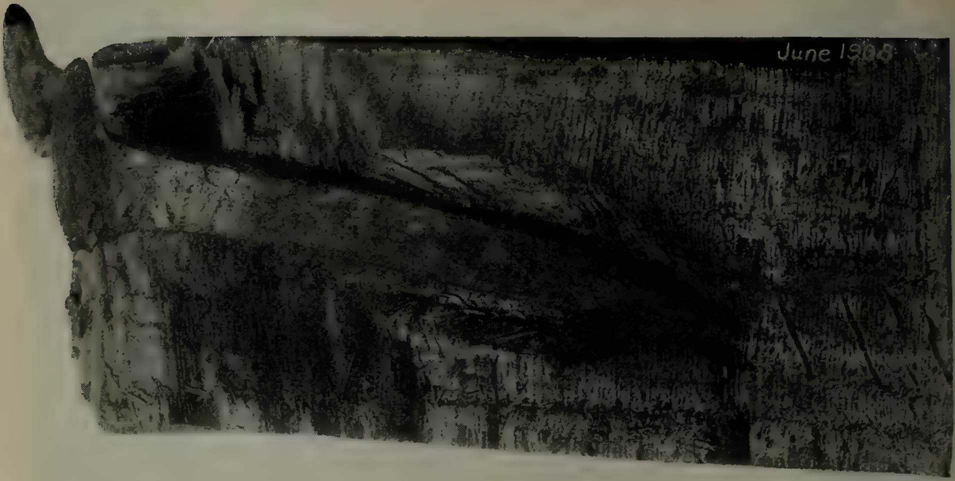


RAIL PENETRATION, SHOWING NO MOVEMENT OF SPIKE. WHITE OAK TIE, IN SERVICE 8 YEARS.

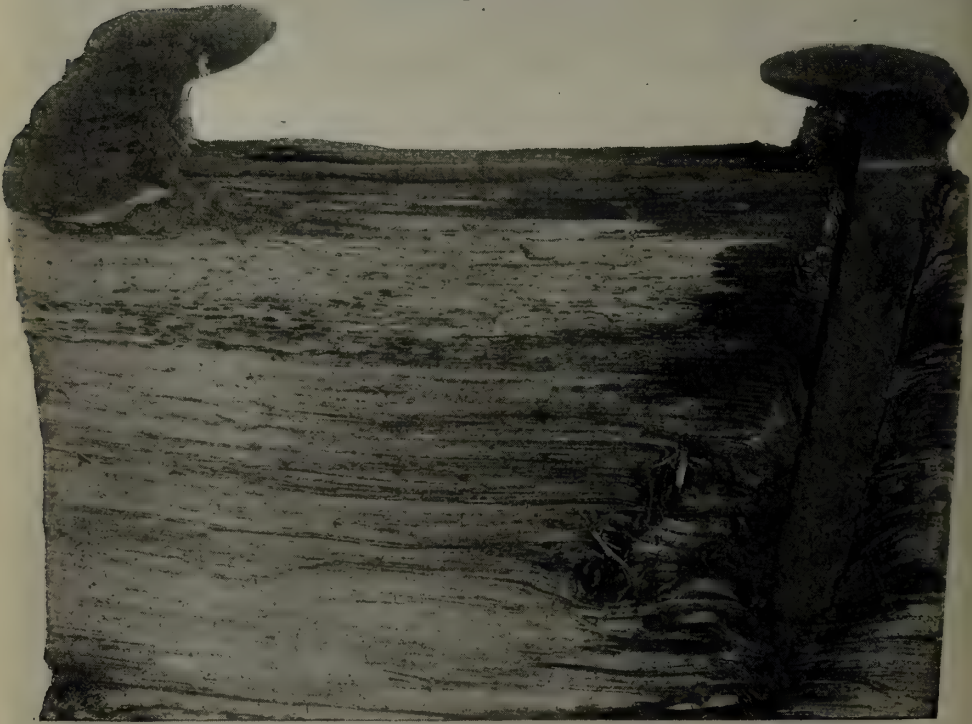


RAIL PENETRATION IN TIE, SHOWING POSITION OF SPIKE AND DISPLACEMENT OF WOOD FIBER. OAK TIE, IN SERVICE 8 YEARS.
RAIL CUTTING, ⅞ INCH.

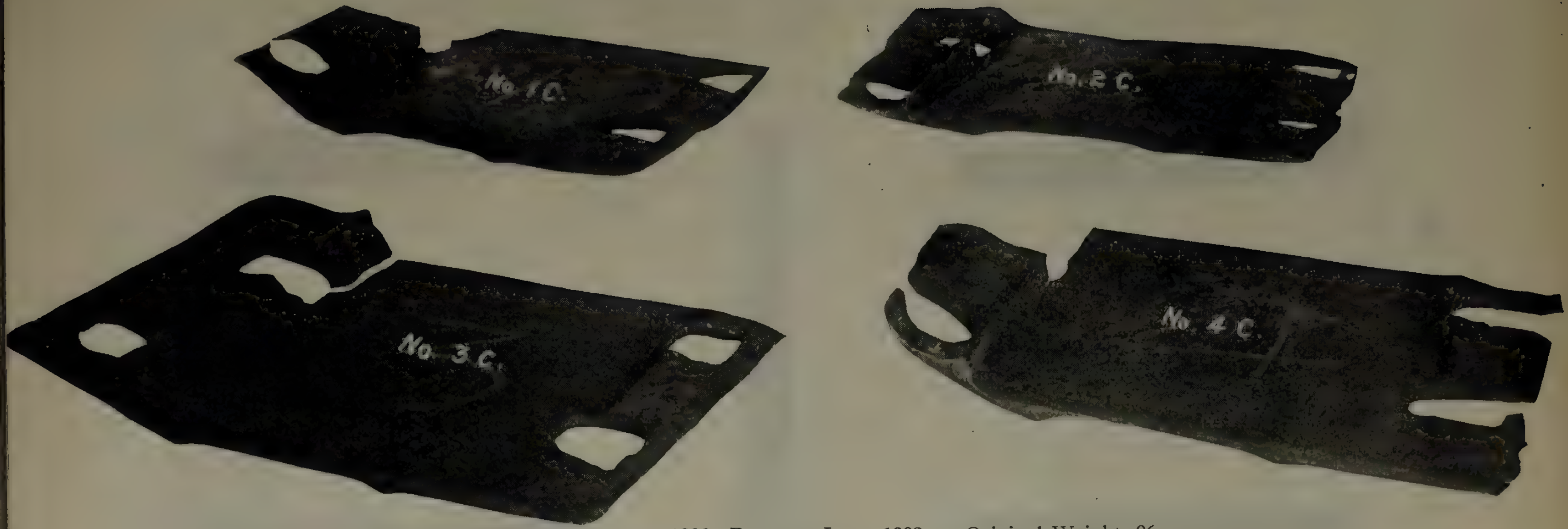
Philadelphia Division.



Rail Penetration in Tie, Showing Position of Spike and Displacement of Wood Fiber. Oak Tie, in Service 8 Years.
Rail Cutting, 7/8 Inch.
Philadelphia Division.



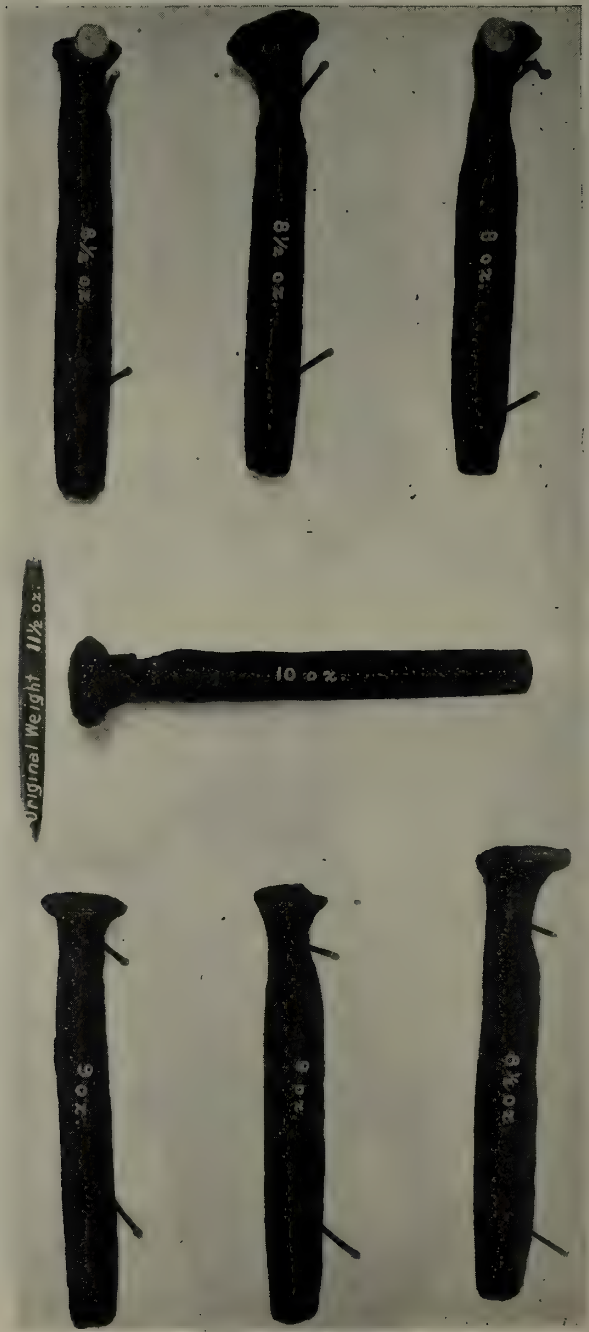
Rail Penetration, Showing No Movement of Spike. White Oak Tie, in Service 8 Years.
Philadelphia Division.



No. 2 Track, Applied, 1903; Removed July, 1908. Original Weight, 96 oz.

	Present Wt.	Loss.
No. 1	37 oz.	59 oz.
No. 2	48 oz.	48 oz.
No. 3	46 oz.	50 oz.
No. 4	44 oz.	52 oz.

Pittsburgh Division.



No. 2 Track. Applied, 1903; Removed July, 1908.
Pittsburgh Division.

TESTS OF HOLDING POWER OF ROUND AND SQUARE TRACK SPIKES WITH POINTS OF DIFFERENT SHAPES.

"A"

TEST OF ROUND AND SQUARE TRACK SPIKES—FEBRUARY 27, 1909

Test No.	*Kind of Spike*	*Kind of Point*	*Diam. of Hole*	*Force Required (lbs.) Yellow Pine To Drive*	*Yellow Pine To Extract*	*White Oak To Drive*	*White Oak To Extract*
2	⅝″ □	Chisel	......	4220	4220	9580	9540
8	¾″ □	"	......	4960	4140	10660	9090
3	⅞″ o	"	½″	6880	4700	11000	10280
4	⅞″ o	"	½″	4980	4340	11400	9410
5	⅞″ o	Chamfered	½″	7250	4290	10280	9440
6	⅞″ o	Chamfered & Flattened	½″	5210	4240	12470	10240
7	⅞″ o	Blunt & Conical	½″	6360	4620	10440	9830

TEST "B" OF ROUND AND SQUARE TRACK SPIKES—MARCH 16, 1909

Test No.	*Kind of Spike*	*Kind of Point*	*Force Required (lbs.) Yellow Pine To Drive*	*Yellow Pine To Extract*	*White Oak To Drive*	*White Oak To Extract*
1	1-⅛″ o	Chisel	Tie Split		Tie Split	
2	1″ □	"	12770	8590	17670	12740
3	1″ o	"	7750	4460	Tie Split	
4	⅞″ □	"	12200	7180	14460	11560
5	1″ o	"	9770	7510	12440	10010
6	⅞″ □	"	12530	7700	14910	9380
7	1-⅛″ o	"	Tie Split		16150	12280
8	1″ □	"	Tie Split		17620	11700

TEST "C" OF ROUND AND SQUARE TRACK SPIKES—MARCH 22, 1909

Test No.	*Kind of Spike*	*Kind of Point*	*Size of Hole*	*Force Required (lbs.) White Oak Timber To Drive*	*White Oak Timber To Extract*
1	⅞″ □	Chisel	⅜″	12400	10020
2	1″ o	"	⅜″	12250	10500
3	⅞″ □	"	½″	11320	10600
4	1″ o	"	½″	11590	10320
5	1″ □	"	½″	17680	12150
6	1-⅛″ o	"	½″	14000	11100
7	1″ □	"	⅜″	14920	13000
8	1-⅛″ o	"	⅜″	15000	13650
9	⅞″ □	"	¾″	10950	8950

NOTE:—Penetration 5 inches for all above tests. Tests made by Riehle Bros. under supervision of C. G. Davis.

TEST "D" OF SQUARE TRACK SPIKES—APRIL 14, 1909

Test No.	*Kind of Spike*	*Kind of Point*	*Number of Tie*	*Force Required (lbs.) White Oak Timber*	
				To Drive	*To Extract*
1	5/8"	Chisel	1	6800	3430
2	"	"	"	9850	6060
3	"	"	"	9900	8180
4	"	"	"	9450	4000
5	"	"	"	9500	5890
6	"	"	"	11500	12630
7	"	"	"	12120	12440
8	"	"	"	10550	12330
9	"	"	"	12100	9540
10	"	"	"	9000	5110
11	"	"	2	13450	7770
12	"	"	"	15590	9290
13	"	"	"	12280	10040
14	"	"	"	14000	12350
15	"	"	"	12160	9450
16	"	"	"	12300	10510
17	"	"	"	12220	8500
18	"	"	"	12650	9150
19	"	"	"	12400	10320
20	"	"	"	13050	10660
21	"	"	3	9850	7640
22	"	"	"	10920	11950
23	"	"	"	12180	12150
24	"	"	"	16000	14360
25	"	"	"	13000	12310
26	"	"	"	12450	12830
27	"	"	"	10750	13320
28	"	"	"	11330	12560
29	"	"	"	11820	11640
30	"	"	"	10630	10600
31	"	"	4	11200	12910
32	"	"	"	10850	9550
33	"	"	"	10720	11200
34	"	"	"	12340	11550
35	"	"	"	12590	12420
36	"	"	"	19920	13000
37	"	"	"	11460	11400
38	"	"	"	12680	12360
39	"	"	"	12470	12070
40	"	"	"	12110	12050
41	"	"	5	12580	12580
42	"	"	"	10750	11880
43	"	"	"	10230	14380
44	"	"	"	10710	10740
45	"	"	"	11520	11250
46	"	"	"	12270	11360
47	"	"	"	10070	11290
48	"	"	"	11150	11520
49	"	"	"	9680	7650
50	"	"	"	10590	12710
Averages	"	"	2, 3, 4 & 5	12181	11375

NOTE:—All tests in tie No. 1 omitted from averages because of tie splitting. Test No. 21 omitted from averages because of spike head pulling off.

Test No.	*Kind of Spike*	*Kind of Point*	*Number of Tie*	*Force Required (lbs.) White Oak Timber*	
				To Drive	*To Extract*
1	¾″	Chisel	1	13550	7860
2	“	“	“	12050	7020
3	“	“	“	10860	6960
4	“	“	“	12760	8340
5	“	“	“	9100	6420
6	“	“	“	13020	7270
7	“	“	“	12640	11910
8	“	“	“	12550	8620
9	“	“	“	11000	10140
10	“	“	“	8950	7680
11	“	“	2	15000	10120
12	“	“	“	14650	11400
13	“	“	“	15780	10770
14	“	“	“	14990	12150
15	“	“	“	12460	9190
16	“	“	“	11670	8000
17	“	“	“	13830	9010
18	“	“	“	14270	8980
19	“	“	“	13810	9760
20	“	“	“	14740	13600
21	“	“	3	14310	12630
22	“	“	“	14210	10690
23	“	“	“	13190	11960
24	“	“	“	10930	7400
25	“	“	“	12330	10220
26	“	“	“	13570	15000
27	“	“	“	13500	11350
28	“	“	“	13670	14910
29	“	“	“	12350	9420
30	“	“	“	13260	13260
31	“	“	4	12730	11150
32	“	“	“	13520	11020
33	“	“	“	11420	9320
34	“	“	“	12150	9880
35	“	“	“	13160	9410
36	“	“	“	13050	9600
37	“	“	“	12290	11170
38	“	“	“	12450	11690
39	“	“	“	12600	11290
40	“	“	“	12200	10260
41	“	“	5	11560	10960
42	“	“	“	11330	13350
43	“	“	“	12070	9150
44	“	“	“	11890	8650
45	“	“	“	11130	12300
46	“	“	“	13780	14630
47	“	“	“	11980	11120
48	“	“	“	11610	12850
49	“	“	“	12080	13050
50	“	“	“	12220	13220
Averages	“	“	2, 3, 4 & 5	13030	11276

NOTE:—All tests in tie No. 1, also tests No. 16 and No. 24, omitted from averages because of tie splitting.

Test No.	*Kind of Spike*	*Kind of Point*	*Number of Tie*	*Force Required (lbs.) White Oak Timber*	
				To Drive	*To Extract*
1	⅞″	Chisel	1	17450	8200
2	"	"	"	13240	7580
3	"	"	"	15420	8000
4	"	"	"	14000	5260
5	"	"	"	14130	8440
6	"	"	"	16500	8030
7	"	"	"	16000	5520
8	"	"	"	16440	13650
9	"	"	"	15400	8630
10	"	"	"	15000	5790
11	"	"	2	20270	11350
12	"	"	"	20600	13350
13	"	"	"	16420	11230
14	"	"	"	17690	11400
15	"	"	"	16310	13830
16	"	"		16120	10330
17	"	"	"	20040	11830
18	"	"	"	17850	9350
19	"	"	"	17560	10860
20	"	"	"	20000	10830
21	"	"	3	17000	14300
22	"	"	"	15440	12750
23	"	"	"	16130	14520
24	"	"	"	17080	15600
25	"	"	"	17280	11860
26	"	"	"	16110	11890
27	"	"	"	17050	13670
28	"	"	"	15760	15450
29	"	"	"	17160	12890
30	"	"	"	19000	12880
31	"	"	4	17220	12300
32	"	"	"	17180	12000
33	"	"	"	16000	11320
34	"	"	"	14450	13890
35	"	"	"	15520	13520
36	"	"	"	16960	13160
37	"	"	"	16290	12380
38	"	"	"	16420	15190
39	"	"	"	15790	10920
40	"	"	"	15480	11570
41	"	"	"	17440	10400
42	"	"	5	17810	15410
43	"	"	"	16130	6180
44	"	"	"	14980	12580
45	"	"	"	15510	9430
46	"	"	"	15580	8250
47	"	"	"	15820	9000
48	"	"	"	14990	12330
49	"	"	"	13500	9430
50	"	"	"	14100	12390
Averages	"	"	2, 3, 4 & 5	16716	12196

NOTE:—All tests in tie No. 1 omitted from averages because of tie splitting. Test No. 43 omitted because of spike bending.

AVERAGES OF TESTS IN TIES NOS. 2 TO 5 INCLUSIVE

	5/8"	3/4"	7/8"
Area (inches)	.391	.563	.766
To Drive (lbs.)	12181	13030	16716
To Extract (lbs.)	11375	11276	12196
Area (% of 5/8)	100	144	196
To Drive (% of 5/8)	100	107	137
To Extract (% of 5/8)	100	99	107

NOTE:—Penetration 5 inches for all above tests. Tests made by Riehle Bros. under supervision of C. G. Davis.

TEST ON DRIVING SCREW SPIKES—WEST PHILA.—MARCH 20, 1909

1" and 3/4" spikes, plan 59629—holes 3/4" and 1/2"—socket wrenches 15" and 14" handles—2 men to each wrench driving spikes

Test No.	*Time in minutes and seconds required for*					
	Boring Holes		*Driving Spikes*		*Extracting*	
	3/4"	1/2"	1"	3/4"	1"	3/4"
1	1' 15"	1' 00"	1' 15"	1' 15"		
2	1' 00"	40"	40"	25"		
3	40"	30"	45"	25"	20"	12"

Communication from Mr. James McCrea, President, dated March 9, 1910.

Subject:—Two Points for Consideration by the Committee on Screw-Spike Test.

April 2, 1910.

Respectfully returned to,
Mr. W. H. Myers,
General Manager.

I have taken up with the members of the Joint Committee on Screw-Spike Test, the two questions raised by President McCrea, and beg to report at follows:

Referring to the first question:

> "Is it a fair test to give such perfect preparation to the "track as seems to be contemplated? Will the results be those "which may be anticipated in connection with the general condi-"tions of maintenance on the whole length of our line? Will "they not be the results of tests made under really abnormal "conditions?"

It is the unanimous opinion of the Committee that, while our reports of the installation of this track would convey the impression that more effort than is our usual practice had been expended to produce a section of track as nearly perfect as possible, such is not, in reality, the case. A fair and equitable comparison requires that the track conditions be made as nearly up to our standard as possible, and in order to attain this, it was necessary to equalize the depth of ballast under the experimental track, otherwise some parts of the experiment would not have a standard depth of ballast beneath the ties, which would have been obviously unfair.

When building additional main tracks, or when renewing old tracks, we aim to construct it in fully as good shape as we are building this.

In the matter of maintenance, it is not intended to give this experimental track any more attention than is required to keep it up to the same standard of excellence which we strive to attain with all our main tracks, so that its condition should not be any closer perfection than on any other section of track of equal length and under similar traffic conditions; and if, as we hope, the form of construction proves superior to our present track, there will be less work done on it. In any case, we intend the comparison to be fair in every way. It will be noticed that we include two sections fastened with the ordinary spikes (one with tie-plates, and one without), which were laid, and will be maintained, under the same conditions as the sections with screw-spikes; so that the comparison between the present standard construction and the different new holding devices will be under exactly the same conditions.

Referring to the second question:

> "The recent accident to the St. Louis 24-hour Train near "Scio, on the Pittsburgh Division of the P. C. C. & St. L., was "occasioned by a very bad breakage of a rail which, as I understand, had been in service for two or three years, long enough, "at all events, to have developed any ordinary weakness. The "track is reported to have been in most excellent condition, the "ties having been treated and the rails fastened to the ties by "screw-spikes, and it has occurred to me that perhaps the cause "of this trouble was a lack of elasticity, due to there being no "'give' in the fastening of the rail to the cross-tie. In the case "of a spike, as we all know, a little spring in the rail and 'give' "in the tie, will sometimes draw the spike from an eighth to a "quarter of an inch, whereas, if in the present case the tie was "absolutely frozen in its bed, and no opportunity given for the "rail to spring because of the tight fastening to the tie, a "rigidity would result that might cause a breakage under a blow "from a slightly flattened wheel or any other cause, that would "have been relieved by a little elasticity."

I enclose Mr. Cushing's reports in full, with reference to the wreck of No. 30, the 24-hour New Yorker, near Scio, on February 20th, and, in short, he states: "It is my opinion that the screw-spike had nothing "to do with the accident. It is a case of failure of a defective rail in "a lot of rail which has given a good many failures. The piece submitted "to me showed a cleavage streak in the web and it has been sent to "R. W. Hunt & Co., for examination, the report not yet having been "received. * * * A good many of the screw-spikes have been broken "and bent and a good many have also been found loose. * * * "These facts show that the track is not unduly stiff."

"Irrespective of the above, however, I am a believer in stiff track "as a necessary part of improved track construction which we must have "absolutely to keep up with the increased weight of rolling stock. It "should be our effort to reduce wave motion in rail by having a stiffer "rail and a better roadbed."

"The Division Engineer reports that he has watched this track "closely since it was put in in September, 1907, 2½ years ago, and has had "frequent inspections made by representatives from his office, and they "are of the opinion that the screw-spikes have not in any way increased "the danger. At the time of the accident, the track was in good condition and the ballast was not frozen to any great depth."

In the report of Division Engineer W. D. Wiggins to Superintendent P. A. Bonebrake, we find the following: "A part of the broken rail "shows a pipe or flaw in the web and I think this was the cause of the "derailment. * * * The accident occurred at about the middle of "a 1 degree 31 minute curve. The broken rail was located on the high "side of the curve. * * * The superelevation of the rail on this curve "was 3¼ inches."

In Mr. Johnson's letter, attached in full, he states: "I have always "held that any device which fastened the base of rail rigidly in contact "with the cross-tie, must operate conversely and lift the tie off its bed, "to follow the upward movement of the rail after the passage of a train. "This will make a track 'churn' badly in wet weather, and in freezing "weather, the tie will be held in its lifted position until the wheel is over, "or nearly over it, when the grip of the ice is broken, and the tie drops "suddenly to its depressed bed. The next tie ahead being still held up in "the same way, the rail cannot adjust itself to the normal curve of the "advancing wave, and must take a short bend over the shoulder of the "forward tie. This condition coupled with the suddenness of its occurrence, and low temperature of the rail, can only result in a dangerous "tendency to fracture."

This question, as to whether the rail should or should not be secured and held hard and fast to the cross-tie, is a much discussed one. From my own experience I believe that any form of construction that lacks elasticity to some degree—depending largely on the stiffness of the rail and the rise and fall of the wave of the rail ahead under and following the passing wheel—will result in damaging the rail and roadbed, and also the rolling stock. I believe we will save many accidents and much trouble and expense "by a little elasticity" in our roadbed, and that our experiments, as continued, will show that it will be economical to avoid the "churning" of the tie by leaving a small space between the upper surface of the base of the rail and the under side of the head of the screw-spike.

Respectfully yours,

(Signed) Jos. T. Richards,

Chief Engineer Maintenance of Way, Chairman, Joint Committee on Screw-Spike Test.

UNIT LOAD CAPACITY OF WOOD TIES.

THE PENNSYLVANIA RAILROAD COMPANY.

Altoona, Pa., November, 11, 1914.

Subject: Repeated Applications of Load to White Oak Tie.

Mr. W. G. Coughlin,
Engineer Maintenance of Way.

Dear Sir:

Replying to your letter of October 5th, and in further reference to our conversation relative to the question of repeated applications of load to a cross-tie to determine the effect on the surface fibers.

Your letter arrived at a time when our spring testing machine was broken down and it is, therefore, impossible for us to make any repeated loading tests. We have, however, made an investigation on a white oak tie in our tensile machine which has furnished us some rather interesting results. These results were obtained by making a heavy steel block, 7 inches by 11 inches, equal to 77 sq. in., which was placed on the tie and loaded to determine what load would be required to crush the surface fibers of the tie. The first load applied was 123,200 lbs., corresponding to a load per square inch of 1600 lbs. It was found that the block readily crushed into the tie with this load. This was then reduced to 100,000, 38,500 and 30,800 lbs., with corresponding loads per square inch of 1300, 500 and 400 lbs., respectively. Under these loads it was apparent that rupture of the surface fibers would commence when the pressure was about 400 lbs. per square inch, but the rupture did not take place immediately upon the loading. We then placed the tie under load for 24 hours, keeping the load balanced by running the top head of the machine down as the tie gave way under pressure. Results of this 24-hour test at 30,800 lbs. are plotted on sheet No. 9537, which is attached. The curve you will note is somewhat in the form of a parabola, indicating that the tie squeezes out under the load rather rapidly at first, but practically nothing at the end of 24 hours. The marking on the tie under this condition is shown on photograph T-4565, and you will note that although the fibers have apparently just started to rupture, that the indication is but slight, the movement down of the head in order to keep the machine balanced apparently causing a general squeezing out of the material in the tie rather than an excessive crushing of the surface fiber.

These results would seem to indicate that the minimum ultimate strength of the surface fiber of an oak tie is in the neighborhood of 400 lbs. per square inch and that whenever this load is exceeded, a rupture of the fiber should be expected.

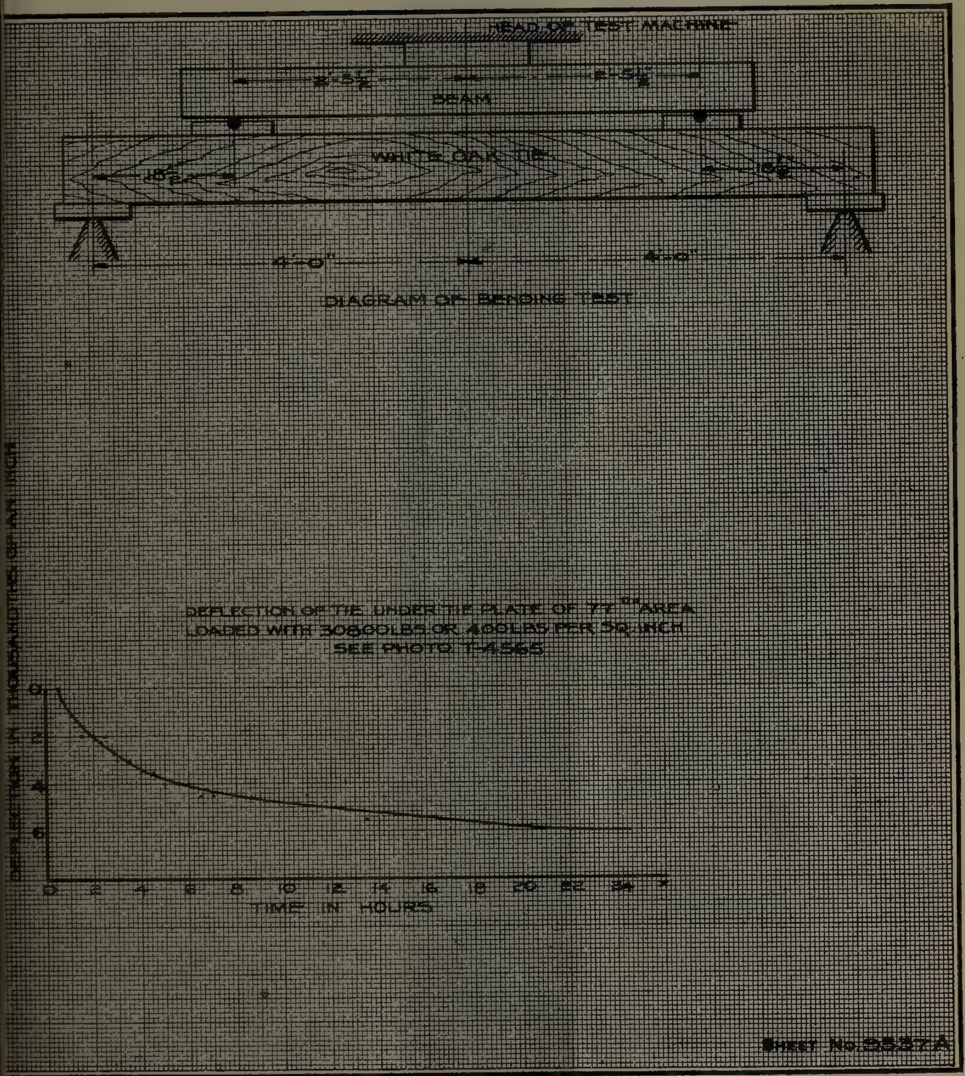
We then placed the tie in the machine and applied a load to the tie at the point corresponding to the position of the tie-plate on the tie in track and supported the tie at the ends, as shown in sketch, sheet No. 9537, attached, in order to have combined flexure and load. A load of 40,000 lbs., 20,000 lbs. on each tie-plate, deflected the tie 2.15 inches at center and tie took a permanent set of 0.23 inch. This load was then increased to 42,740 lbs. and under this load the tie deflected 2.20 inches and commenced to crack. The tie broke by splitting near the center at a load of 45,000 lbs. and showed a deflection of approximately 2.6 inches at the center at time of breaking. There was no appreciable crushing of the fibers of the surface under the tie-plates which carried a load of 290 lbs. per sq. in. at the total load of 45,000 lbs. on the blocking.

From these results we are rather inclined to believe that the failure of the tie is due to the deterioration of the fibers on the surface and not to the flexure of the tie itself, and that such flexure comes about as a result of the weakening of the fibers due to crushing at the surface, after which crushing has taken place and the tie then loaded as a beam, it breaks, due to localizing the stress at the weakest point in the beam. All of the above would seem to indicate that the proper procedure for increasing the life of the tie would be to reduce the unit load per square inch on the surface. This can be accomplished either by better contact of the tie-plate to the tie, requiring a dressing of the surface at the point of contact, or increasing the size of the tie-plate and distributing the load properly so as not to exceed for a white oak tie a load of 400 lbs. per square inch under the maximum traffic condition.

We hardly feel that these results are conclusive from the apparatus with which we have worked, but we do feel that the tests give a general indication as above stated.

Yours truly,

(Signed) C. D. Young,
Engineer of Tests.


HEAD OF TEST MACHINE
2'-5½"
2'-5½"
BEAM
WHITE OAK TIE
10½"
10½"
4'-0"
4'-0"
DIAGRAM OF BENDING TEST
DEFLECTION OF TIE UNDER TIE PLATE OF 77 □" AREA
LOADED WITH 30800LBS OR 400LBS PER SQ INCH
SEE PHOTO T-4565
DEFLECTION IN THOUSANDTHS OF AN INCH
0
2
4
6
0
2
4
6
8
10
12
14
16
18
20
22
24
TIME IN HOURS
SHEET No. 5537A

Repeated Application of Load to White Oak Tie.
T-4565.

THICKNESS OF TIE-PLATE NECESSARY TO DISTRIBUTE LOAD EVENLY OVER ITS AREA TO THE TIE.

September 26, 1913.

Members Screw-Spike Committee.

Gentlemen:

Enclosed please find copy of a report of tests of tie-plates made at Altoona, the types tested being Type 7 New York Tunnel tie-plate, 5/8 inch thick. Plain Rolled Steel tie-plate 23/32 inch thick, and Type 6 Malleable Iron tie-plate 1 15/16 inch thick. The tests were made by placing eight rows of steel balls on a copper plate under each of the three different kinds of tie-plates, and applying a load of 70,000 lbs. on a superimposed rail section.

You will note that the pressure near the outer edges of the 5/8 inch tie-plate was about one-sixth of the pressure under the rail, in the case of the 23/32 inch plate it was about one-third, while, in the case of the 1 15/16 inch plate it was about two-thirds, showing that the thick plate distributes the load much better than the thin one, which was to be expected, and probably accounts for the outer edges of the Type 6 tie-plate, in the experimental track at Birmingham and Wooster, cutting into the tie to a somewhat greater extent than Type 7.

In this connection it should be borne in mind that the inclination of the rail, due to cutting at the outer edge of the plate, will result in a greater widening of the gage, in the case of the thick plate, than the thinner one, on account of the longer lever arm, and, while the thick plate affords better distribution of the load it is a question whether this is an advantage beyond a certain point, as was indicated by the results of an investigation we made last summer, when we found that out of about 3500 5/8 inch plates, after from one to four years' service, only 17 were found bent as much as 1/8 inch, and these were all under the low rail on curve, in our loaded freight track on chestnut ties, and had been in track four years.

We are sending you this with the thought that it might prove interesting in connection with the study we are now making for a new design of tie-plate.

Yours truly,

(Signed) L. R. ZOLLINGER,
Chairman Screw-Spike Committee.

September 9, 1914.

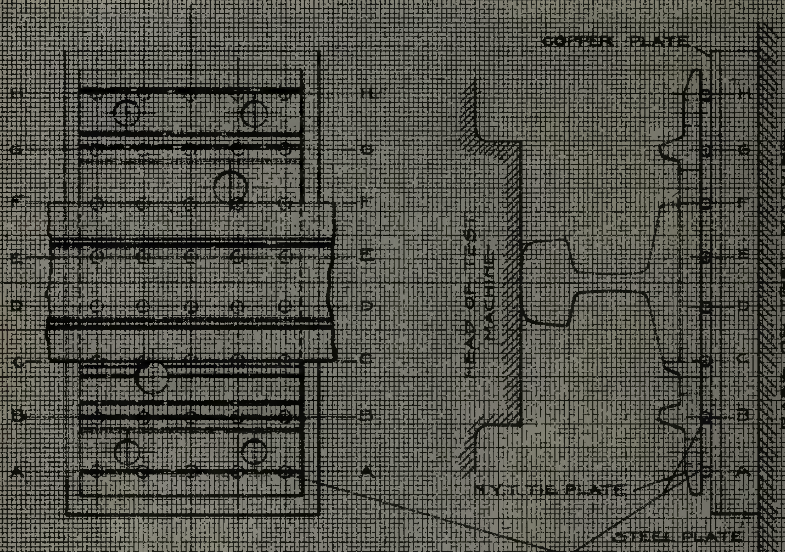
Mr. W. G. Coughlin,
Engineer Maintenance of Way.

Dear Sir:

In accordance with your request of our Engineer of Tests at meeting of Committee on Tie-Plates in Altoona, September 3rd, we have made additional tests of wrought tie-plates, one two inches thick and the other one inch thick, the idea being that the two-inch plate would have sufficient thickness to distribute the load in about the same proportion as the cast plate chair shown on M. W. tracing No. 59734, p. 33, the plates, however, having a length of 16 inches.

The results of tests of the cast plate chair are shown on sheet No. 8132, p. 133, the per cent. of area under rail being 38.5 and the per cent.

Report No. 13-131.



TEST READINGS TAKEN FROM IMPRESSIONS
MADE BY 10 M.M. DIA. BALLS

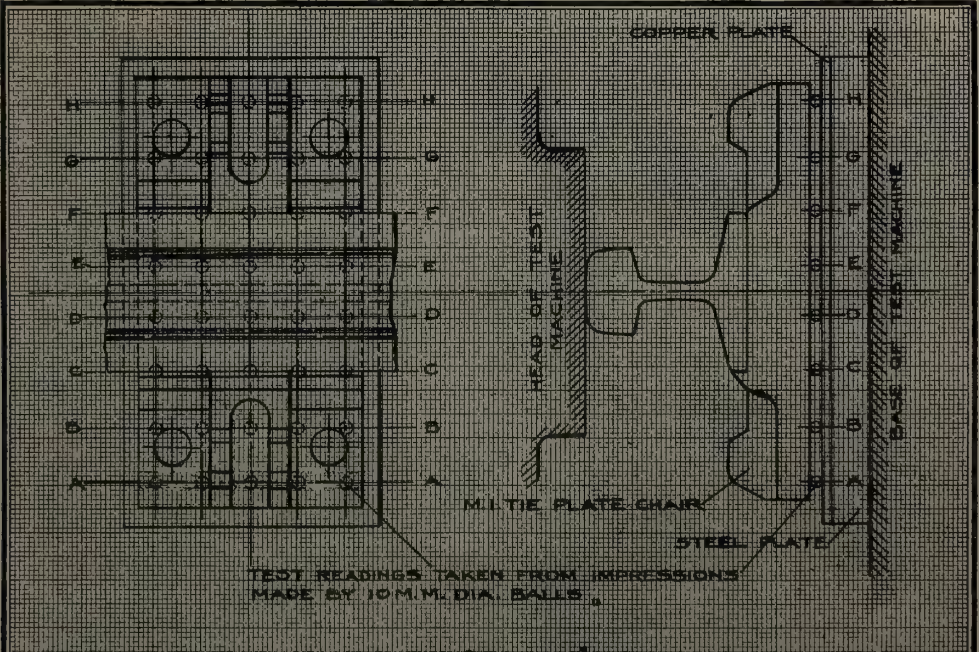
TESTS OF NEW YORK TUNNEL TIE PLATES .625" THICK

ACTUAL LOAD APPLIED	LOADS TRANSMITTED	LOCATION OF LOAD TRANSMITTED				
		A – A	B – B	C-D-E-F	G – G	H – H
70000 POUNDS	POUNDS	1961	4646	55252	6812	1329
	% LOAD APPLIED	2.80	6.64	78.93	9.73	1.90
60000 POUNDS	POUNDS	1323	4258	48288	5475	656
	% LOAD APPLIED	2.20	7.10	80.48	9.13	1.09
50000 POUNDS	POUNDS	1490	3517	38094	5560	1339
	% OF LOAD APPLIED	2.99	7.03	76.19	11.12	2.67

TESTS OF ORDINARY STEEL PLATES

ACTUAL LOAD APPLIED	LOADS TRANSMITTED	LOCATION OF LOAD TRANSMITTED				
		A – A	B – B	C-D-E-F	G – G	H – H
70000 LBS. ON PLATE 765 THICK	POUNDS	3086	7351	50855	6539	2169
	% OF LOAD APPLIED	4.41	10.50	72.65	9.34	3.10
70000 LBS. ON PLATE .909" THICK	POUNDS	4186	7226	47656	7302	3630
	% OF LOAD APPLIED	5.98	10.32	68.09	10.43	5.18

SHEET No. 7551



TEST OF MALL. IRON TIE PLATE CHAIR, 1.5375" THICK. M. OF W. TRAC. NO. 59734.

ACTUAL LOAD APPLIED	LOADS TRANSMITTED	LOCATION OF LOAD TRANSMITTED				
		A-A	B-B	C-D-E-F	G-G	H-H
70000 POUNDS	POUNDS	7294	8644	39688	7944	6430
	% OF LOAD APPLIED	10.42	12.34	56.70	11.34	9.20

No. 8132. September 12, 1913.

of load carried under rail 56.7. The ratio, therefore, of area to the percentage of load carried was 68.

The results of tests of the two-inch plate are shown on sheet No. 9458, p. 170, in which the per cent. of area under rail is 31.3 and gives a percentage of total load under rail of 45.5, this ratio being 69.

You will, therefore, see that the 16-inch plate with two-inch thickness gives approximately the same distribution of load as the cast plate in question.

On this same sheet is also shown the results of tests of a one-inch plate, our reason for making this test was due to the fact that in our calculations the indications were that it was going to require a two-inch plate to get the results in question. We consulted with Mr. Clark to determine what, in his opinion, would be the commercial limitations in thickness, and he advised us one inch. We, therefore, made this test to find out how the load would be distributed. The results of this test indicated that such a plate would be too thin to distribute the load properly, as the per cent. of area under the rail is 31.3, whereas the per cent. of load carried under the rail is 64.7, indicating that double the load would be carried to the tie under the rail as against the rest of the plate.

The results of all tests thus far made are shown in the tabulation below, in which is given the different plates tested, thickness, area of plate on the tie, per cent. of area under and outside of the rail, per cent. of the total load under and outside of the rail, and the ratio of the area under rail to total load under rail.

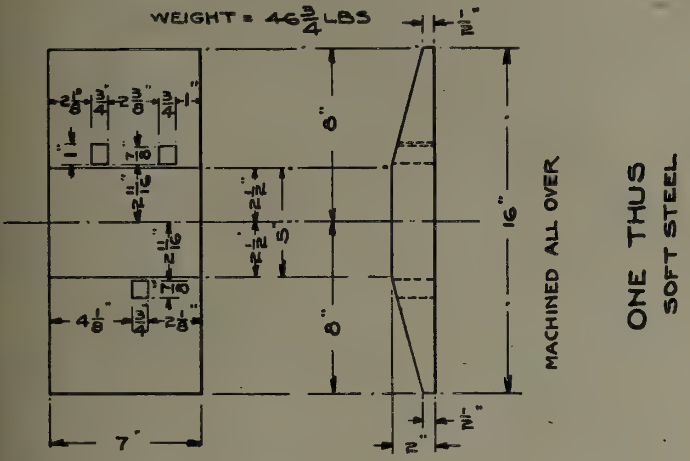
I	2	3	4	5	6	7	8
		Area			*% of Load*		
	Thickness	*Of Plate Sq. In.*	*% Under Rail*	*% Outside Rail*	*% Under Rail*	*% Outside Rail*	*Ratio* $\frac{4}{6}$
Steel Plate..............	.75″	101.5	30.75	69.25	72.65	27.35	42.3
N. Y. Tunnel...........	.625	94.5	37.0	63.0	78.93	21.07	47.0
Cast No. 59734, P. 40....	1.94	91.0	38.5	61.5	56.7	43.3	68.0
W. I. Plate, Tapered....	1.00	112.0	31.3	68.7	64.7	35.3	48.3
W. I. Plate, Tapered....	2.00	112.0	31.3	68.7	45.5	54.5	69
Cast No. 9459, P. 167....	2.25	112.0	31.3	68.7	54.88	45.12	57
*......................	3.63	100.0	40.0	60.0	70.0	30.0	57.1

We have just completed the design of a cast plate which will have a depth of 2¼ inches and which should give results corresponding to the two-inch wrought plate. We are sending the drawing to the shops to-day to have pattern made and will report result of this test to you next week.

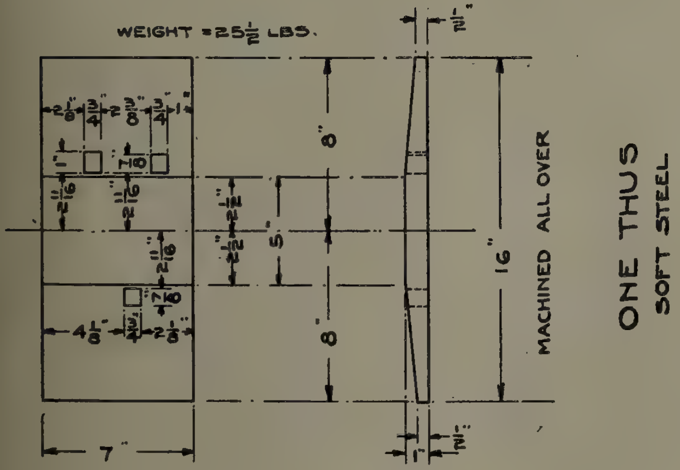
The Test Department has also made up a pencil sketch of testing apparatus which will contain balls to get the the total load upon the rail when various equipment is passing over at different speeds and will forward blueprint of what has been suggested for this purpose for the information of your Committee within the next few days.

Yours truly,

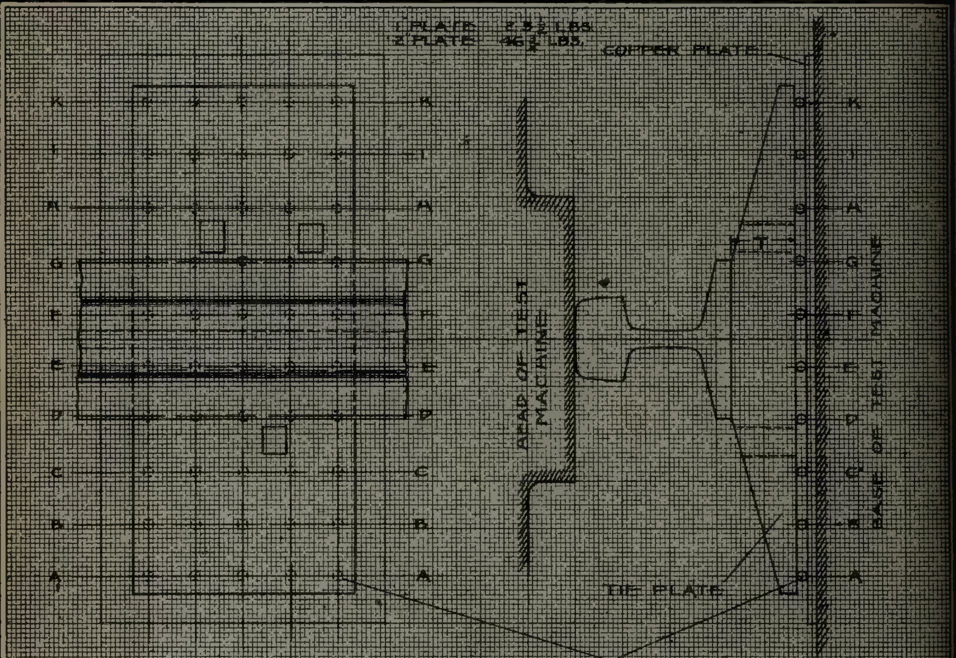
(Signed) J. T. Wallis,
General Superintendent Motive Power.



EXPERIMENTAL



SHEET NO 9457



TEST READINGS TAKEN FROM IMPRESSIONS MADE BY 10 M.M. DIA. BALLS

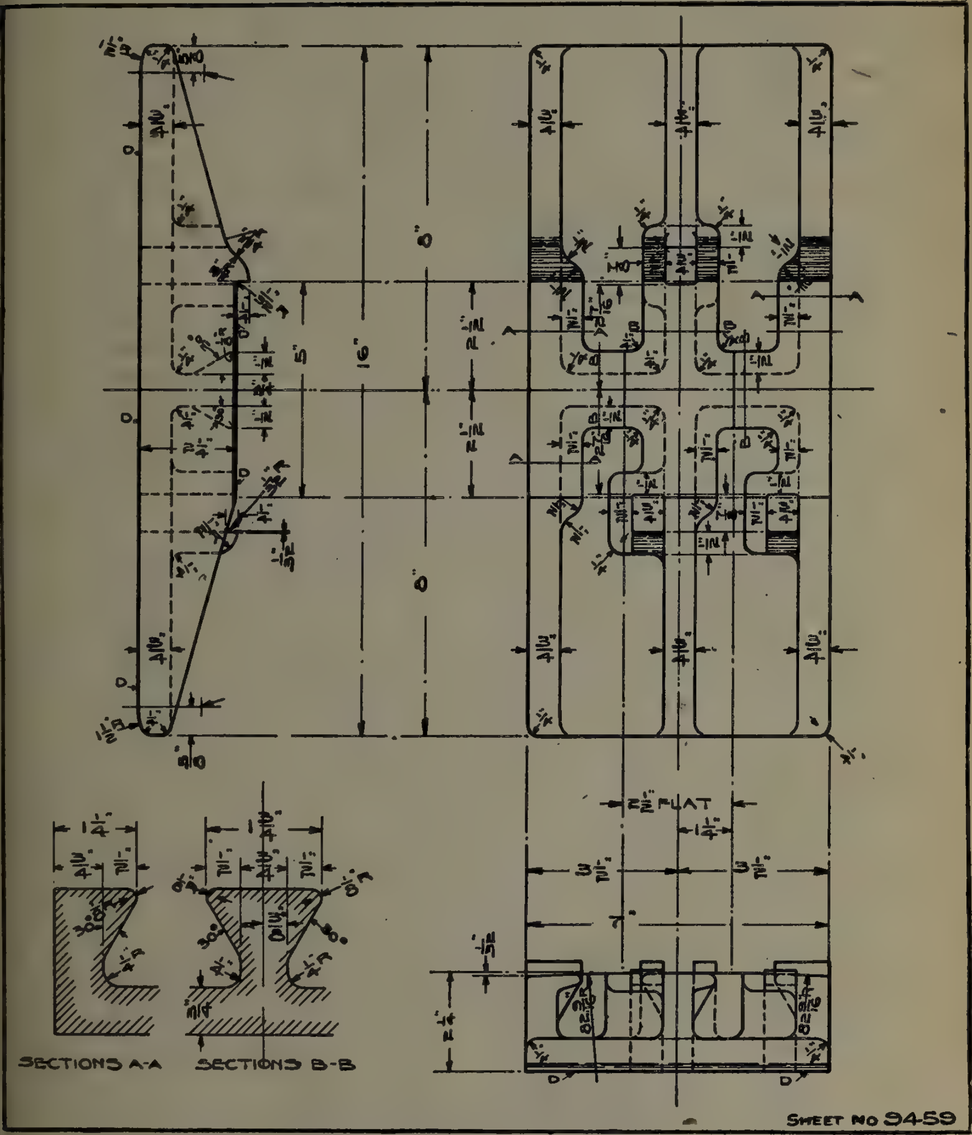
TESTS OF ORDINARY STEEL PLATES. T.D. TRAC. NO. 9457.

ACTUAL LOAD APPLIED	LOADS TRANSMITTED	LOCATION OF LOAD TRANSMITTED						
		A-A	B-B	C-C	D-E-F-G	H-H	I-I	K-K
70,000 LBS. ON PLATE T-1 THICK	POUNDS	1,169	3,240	6,974	45,284	7,736	4,202	1,395
	% OF LOAD APPLIED	1.67	4.64	9.96	64.69	11.05	6.00	1.99
70,000 LBS. ON PLATE T-2 THICK	POUNDS	5,538	6,062	7,055	31,863	7,315	6,723	5,422
	% OF LOAD APPLIED	7.91	8.69	10.08	45.52	10.45	9.61	7.74

TESTS OF CAST IRON TIE PLATE. T.D. TRACING NO. 9459 WT. 34 LBS.

ACTUAL LOAD APPLIED	LOADS TRANSMITTED	LOCATION OF LOAD TRANSMITTED						
		A-A	B-B	C-C	D-E-F-G	H-H	I-I	K-K
70000 LBS. ON C.I. PLATE 2.25" THICK	POUNDS	3602	5286	7626	38415	7469	4315	3287
	% OF LOAD APPLIED	5.15	7.55	10.89	54.88	10.67	6.16	4.70

SHEET NO. 9458.



Cast-Iron Tie-Plate.

Altoona, Pa., November 6, 1915.

Subject: Tests of Tie-Plates.

Mr. W. G. Coughlin,
Engineer Maintenance of Way.

Dear Sir:

For the information of the Screw-Spike Committee certain tests were requested in connection with tie-plates having a length of 16 inches in order to determine the load distribution on the tie under and outside of the rail.

These tests were conducted in a manner similar to those already reported to you under date of September 9, 1914, and we give you herewith a summary of the results:

On sheet No. 10502 we have plotted the results obtained with various widths and lengths of plates, from ⅝ inch to 1 inch in thickness for a load of 38,000 lbs. on rail. These plates were solid or ribbed steel, as marked on sheet No. 10484, and varied in length from 10¾ to 16 inches. The curve shown on sheet No. 10502 is also shown on sheet No. 10503 in its proper location. The data from which this curve is plotted is shown on sheet No. 10484, which contains all the data in connection with the dimension of the plates, distribution of the load, as between under and outside of rail, as well as what the load would be on the tie for the assumed load on rail of 38,000 lbs., representing the maximum on tangent track and 57,000 lbs. on curved track.

On sheet No. 10503 there has been plotted the pressure per square inch on the tie for various thicknesses of plates 16 and 10¾ inches in length, all 7 inches wide. The pressure as plotted is on the assumption that the maximum pressure the rail receives is 38,000 lbs. From the points of distribution of load to the tie as between under and outside of the rail, two curves for each width of plate have been plotted and so marked. This diagram clearly indicates the direction in which the distribution of metal should be if a 16 inch plate is to be used, as compared with a 10¾-inch length of plate and therefore establishes a general rule from which can be determined whether it is advisable to make a long, thick plate or a short, shallow plate. It will be observed that the two upper curves for the 16 inch and 10¾ inch plate give the maximum pressure per square inch which the tie receives under the rail, and therefore these are the ones which establish the maximum wear on the tie under the given load. It will be observed that for plates up to and including 1¼ inch thickness little, if anything, is to be gained by the use of plates 16 inches long, as the load under this condition under the rail will be approximately as severe as if a much shorter plate were used. It is above the thickness of 1½ inches where the value of the long 16-inch plate makes itself apparent, and it would, therefore, seem from the laboratory results as though the 16 inch plate should be used only where a thickness of least 1½ inches under the rail is provided in the design of the plate. This, however, requires a very heavy plate, and therefore would seem as though the 10¾ inch length of plate for any width is more desirable than the 16 inch plate.

An interesting comparison is also shown here from the results, in that the same pressure is received by the tie on two plates of the same identical weight, one being 16 inches long and 1½ inches thick, and the other 10¾ inches long and 2 inches thick. The weight is the same and the pressure received by the tie under the rail is slightly unfavorable to the 10¾ inch plate. This again tends to establish the minimum thickness, namely, 1½ inches, if plates as long as 16 inches are used.

The following table has been made up from the curves for load under rail shown on sheet No. 10503 and the 10¾ inch and 16 inch plates:

			Ratio	
t	$(L=10.75)$	$(L=16)$	$\frac{10.75}{t}$	$\frac{16}{t}$
(1)	(2)	(3)	(4)	(5)
.625	795	780	17.2	25.5
.75	760	745	14.3	21.4
1.0	695	680	10.75	16.0
1.25	650	620	8.6	12.8
1.50	620	570	7.4	10.6
1.75	600	530	6.1	9.2
2.00	585	500	5.4	8.0
2.25	575	475	4.8	7.1
2.50	570	465	4.3	6.4

The first column is "t," or thickness of the plate.

Second column, average load per sq. in. corresponding to the thickness of the plates, which were 10.75 inches long.

Third column, average load per sq. in. corresponding to the thickness of the plates, which were 16 inches long.

Fourth column, ratio of length of plate, 10.75 inches, divided by the thickness.

Fifth column, the ratio of length of plate, 16 inches, divided by the thickness.

By reference to the table it is seen that the value of the 16 inch plate, so far as reducing the pressure on the tie under the rail is concerned, does not make itself apparent until after the plate has reached a thickness dimension (t) greater than 1¼ inches, and that where "t" is 1 inch or less, that plates of 10.75 inches length give practically as good results as the 16 inch plate and have the advantage of considerably less weight of material.

These experiments are too limited in number to form any definite law, but the preliminary tests seem to indicate that where plates of varying length and thickness are 7 inches wide, that so long as length (L) divided by the thickness (t) or $\frac{L}{t}$ is greater than 10.5, the pressure upon the tie under the rail will be about the same, regardless of the values (t) and (L), and that for ratio values $\frac{L}{t}$ above 14, little is to be gained, so far as the load upon the tie is concerned, and that if this ratio value is considerably above 14 the proportions are such as to provide a plate in which there is material which is of no benefit in distributing the load upon the tie.

As would be expected, the distribution of the tie loading is markedly better when the thickness of the plate is greater than one inch. Some reduction is made in weight, by ribbing, without any loss in stiffness for plates thicker than one inch, the relative saving in weight being shown by the following table:

Plate	*Weight*	*Per Cent. Saving in Wt.*
Solid, 7 x 18 x 1 inch	25.5 lbs.	
Ribbed, "	19.75 lbs.	22.5
Solid, 7 x 16 x 2 inch	45.5 lbs.	
Ribbed, "	31.0 lbs.	31.9
Solid, 7 x 10¾ x ¾ inch	13.3 lbs.	
Ribbed, "	12.0 lbs.	9.77

This indicates the saving in material which may be expected from using the ribbed design of tie-plate and is inserted only to indicate the desirability of considering this feature in the design. Photographs T-6258 and 6257 show the appearance of these ribbed plates.

TEST FOR ELASTIC LIMIT OF WOODS IN TIES.

To determine the value of the elastic limit in the woods used in ties we obtained some chestnut ties, 5 years old, marked 1, 2 and 3, furnished by you as per your letter of July 2, 1915, and also obtained the following timber from stock which had not been placed in service: Chestnut, red oak, longleaf yellow pine, white oak and locust.

Loads were applied on these ties with a steel block 7 x 11 inches, and after each increment of load applied the compression noted. Results of these tests are shown on sheets Nos. 10472 to 10479 inclusive. By reference to the sheets it is seen that the results are very erratic, probably due to the character of the material tested, and only an estimate of the elastic limit from the results obtained can be made, which estimate is indicated on each sheet.

The following table is a summary of the elastic limit as estimated, together with the corresponding elastic limit figures given in the Government report. Sheet No. 10060 is also attached showing the crushing strength of various cross-tie woods as furnished by the Government, as well as the estimated life of certain ties. It is noted from this tabulation that the figures as obtained in the laboratory are considerably under those shown by the Government. We are inclined to believe that it would be better to use the Government figures, as undoubtedly a greater variety and larger number of tests were made in order to obtain the figures furnished by them.

	Estimated Elastic Limit	
Kind of Wood	*Laboratory*	*Government Report*
Chestnut, new	450	400
Chestnut, 5-year tie	366	...
Red Oak, new	430	800
Longleaf Yellow Pine	600	600
White Oak	480	900
Locust	750	1400

From these figures the indications are that if the maximum load on the rail is 38,000 lbs. the ties are over-stressed by the use of any plates which are permissible, considering both the values of the Government and the lower values obtained by the laboratory tests.

If the average load as obtained on our road tests is used (which we do not think is proper), namely: 23,000 lbs. (see report sent you under date of May 6, 1915) instead of 38,000 lbs., the load under the rail on the tie for the various thicknesses may be calculated in the ratio 23 to 38 of loads given in Table 2 for 10¾ inch plate, as follows:

Thickness of Plate	*Maximum Pressure* 38000	23000
.625	795	480
.75	760	460
1.00	695	420
1.25	650	395
1.50	620	375
1.75	600	360
2.00	585	355
2.25	575	350
2.50	570	345

From this table, having determined the strength of the tie material to resist abrasion by the selection of a wood having an elastic limit

TESTS OF TIE-PLATES.

Sheet 10484.

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2.50	570	345

From this table, having determined the strength of the tie material to resist abrasion by the selection of a wood having an elastic limit

① B.P.No. of Plate	② Type	③ Size in Inches	④ Area Sq.In.	⑤ Distance Center Line From Edge	⑥ Weight Lbs.	% 70,000 Lb.Load Distribution		⑨ Ratio of % Area Under Rail - To % Load Under Rail	⑩ Area Area Under Rail	⑪ Area Outside of Rail	Maximum Load Under Plate, Lbs.per Sq.In.Assumed Load			
											Tangent 38000#		Curve 57000#	
						Under 100 Lb. Rail ⑦	Total Outside of 100 Lb Rail ⑧				Under Rail ⑫ 38000 x ⑦ / ⑩	Outside Rail ⑬ 38000 x ⑧ / ⑪	Under Rail ⑭ 57000 x ⑦ / ⑩	Outside Rail ⑮ 57000 x ⑧ / ⑪
9458 T.D.	Solid	7x16x2	112	8-8"	46.8	45.5	54.5	69.0	35	77.0	494.0	268.9	740.8	403.5
"	"	7x16x1	112	8-8	25.5	64.7	35.3	48.3	35	77.0	702.5	174.2	1053.7	261.3
9459 T.D.	Ribbed Cl	7x16x2-1/4	112	8-8	34.0	54.9	45.1	57.0	35	77.0	595.7	222.7	894.0	333.9
4-4-14 T.D.	Flanged	8x12-1/2x5/8	100	5-7-1/2	25.0	70.0	30.0	57.1	40	60.0	665.0	190.0	997.5	284.9
"	Solid without flange	8x12-1/2x5/8	100	5-7-1/2	17.0	79.6	20.4	50.2	40	60.0	756.2	129.2	1134.2	193.8
Plain Flat	Solid	14x7-1/4x7/8	101.5	7-7	•26.2	68.09	31.91	45.0	36.25	65.25	713.9	185.7	1070.6	278.7
"	"	14x7-1/4x3/4	101.5	7-7	•22.1	72.65	27.35	42.3	36.25	65.25	761.6	159.2	1142.3	238.9
59629	N.Y.Tunnel	7x13-1/2x5/8	94.5	6-3/4-6-3/4	-	78.93	21.07	47.0	35	59.5	856.5	134.7	1285.4	201.8
59734	Mall.Iron	7x13x1-15/16	91.0	6-1/2-6-1/2	-	56.7	43.3	68.0	35	56.0	615.4	293.9	923.4	440.7
61301 L.E. 10127 T.D.	Solid H.T.	7x10-3/4x11/16	75.25	5-5/8-5-1/8	12.5	70.50	29.50	66.0	35	40.25	765.0	278.5	1148.1	417.8
61301 L.E. 10127 T.D.	Solid	7x10-3/4x11/16	75.25	5-5/8-5-1/8	12.5	67.44	32.56	69.0	35	40.25	732.0	307.4	1098.3	461.7
10127 T.D.	Ribbed	7x10-3/4x3/4	75.25	"	12	68.8	31.20	68.0	35	40.25	747.0	294.6	1120.4	441.8
"	"	7x10-3/4x1	75.25	"	14.5	62.6	37.40	74.3	35	40.25	680.0	353.1	1019.5	529.6
"	" H.T.	7x10-3/4x3/4	75.25	"	12	73.97	26.03	63.0	35	40.25	803.0	245.7	1205.1	366.2
"	" "	7x10-3/4x1	75.25	"	14.5	64.20	35.80	72.4	35	40.25	697.0	338.1	1045.5	507.0
10167 T.D.	" "	7x16x7/8	112.0	9-7	17.25	64.89	35.11	48.2	35	77.0	705.0	173.0	1056.9	259.9
"	"	7x16x1	112.0	"	19.75	61.09	38.91	51.2	35	77.0	663.0	190.0	995.0	288.0
"	" H.T.	7x16x1-7/16	112.0	"	24	53.51	46.49	58.4	35	77.0	581.0	229.0	871.3	344.2
"	"	7x16x1-1/2	112.0	"	25.25	52.91	47.09	59.1	35	77.0	574.0	232.0	863.1	348.7
"	" H.T.	7x16x2	112.0	"	30.75	45.94	54.06	68.0	35	77.0	499.0	267.0	747.5	400.5
"	"	7x16x2	112.0	"	31.5	46.19	53.81	68.0	35	77.0	501.0	266.0	752.4	398.3
"	" H.T.	7x16x2-1/2	112.0	"	35.5	43.04	56.96	73.0	35	77.0	467.0	281.0	700.3	422.0
"	"	7x16x2-1/2	112.0	"	36.25	43.04	56.96	73.0	35	77.0	467.0	281.0	700.3	422.0
10127 T.D.	"	7x10-3/4x1-1/2	75.25	5-5/8-5-1/8	19.0	57.58	42.42	80.8	35	40.25	625.1	400.5	937.7	600.7
"	"	7x10-3/4x2	75.25	"	24	53.80	46.2	86.5	35	40.25	584.1	436.2	876.2	654.3
"	"	7x10-3/4x2-1/2	75.25	"	28.5	52.70	47.3	88.3	35	40.25	572.2	446.6	858.3	669.8

• No taper from edges of rail to plate edges.

TESTS OF TIE-PLATES.

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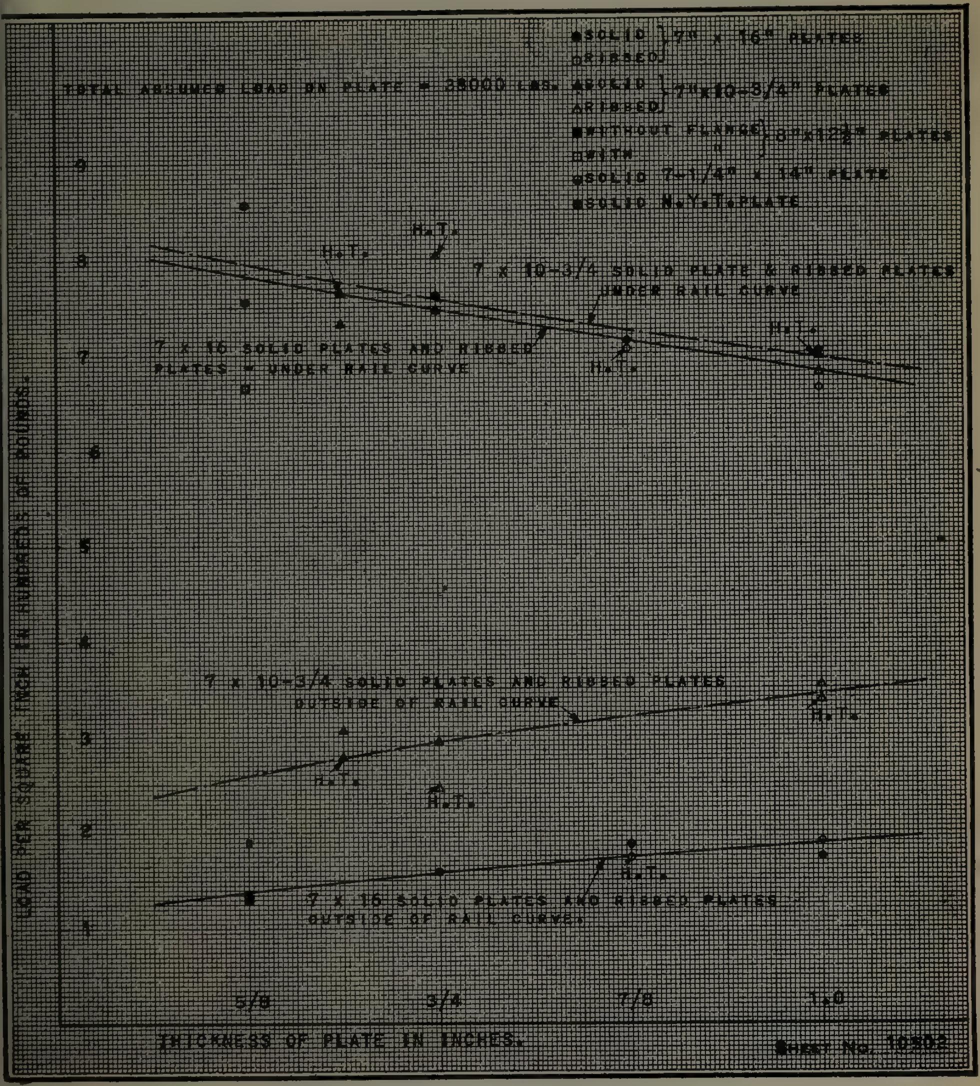
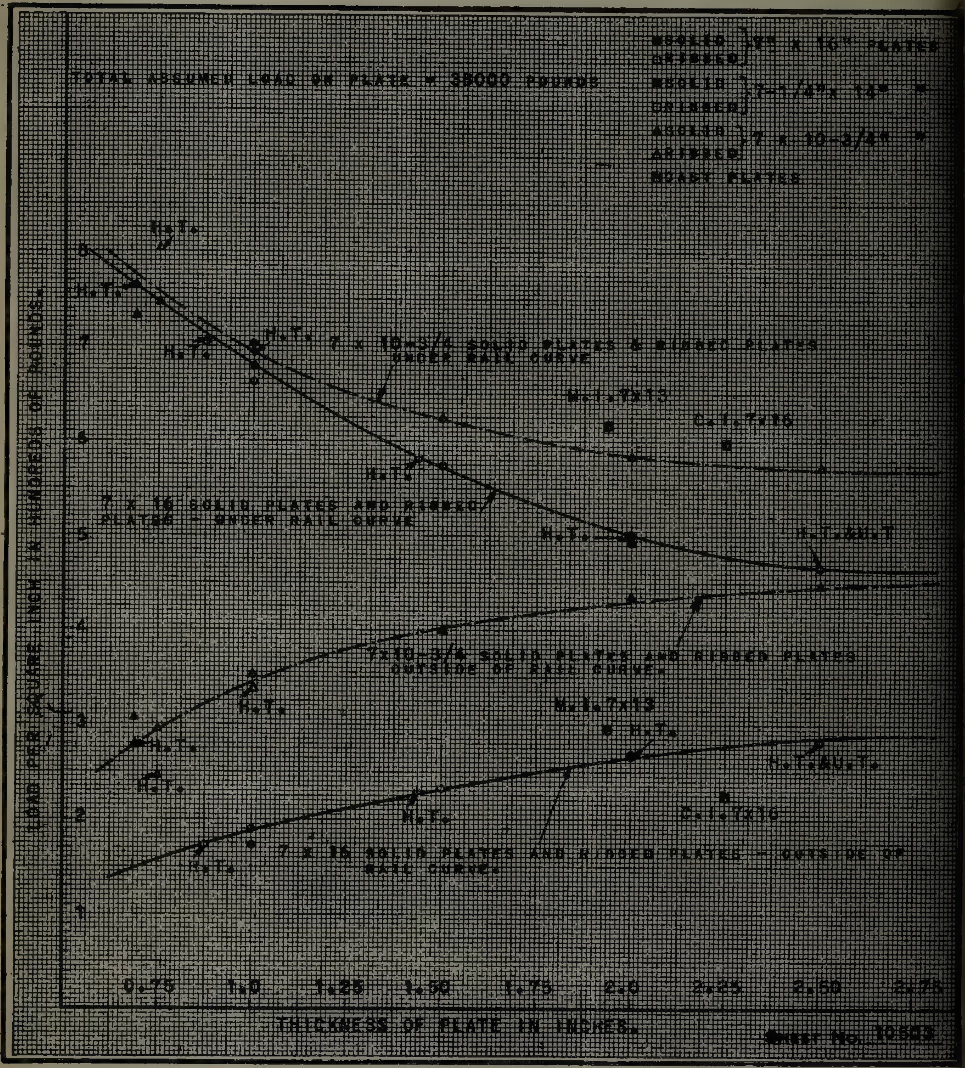
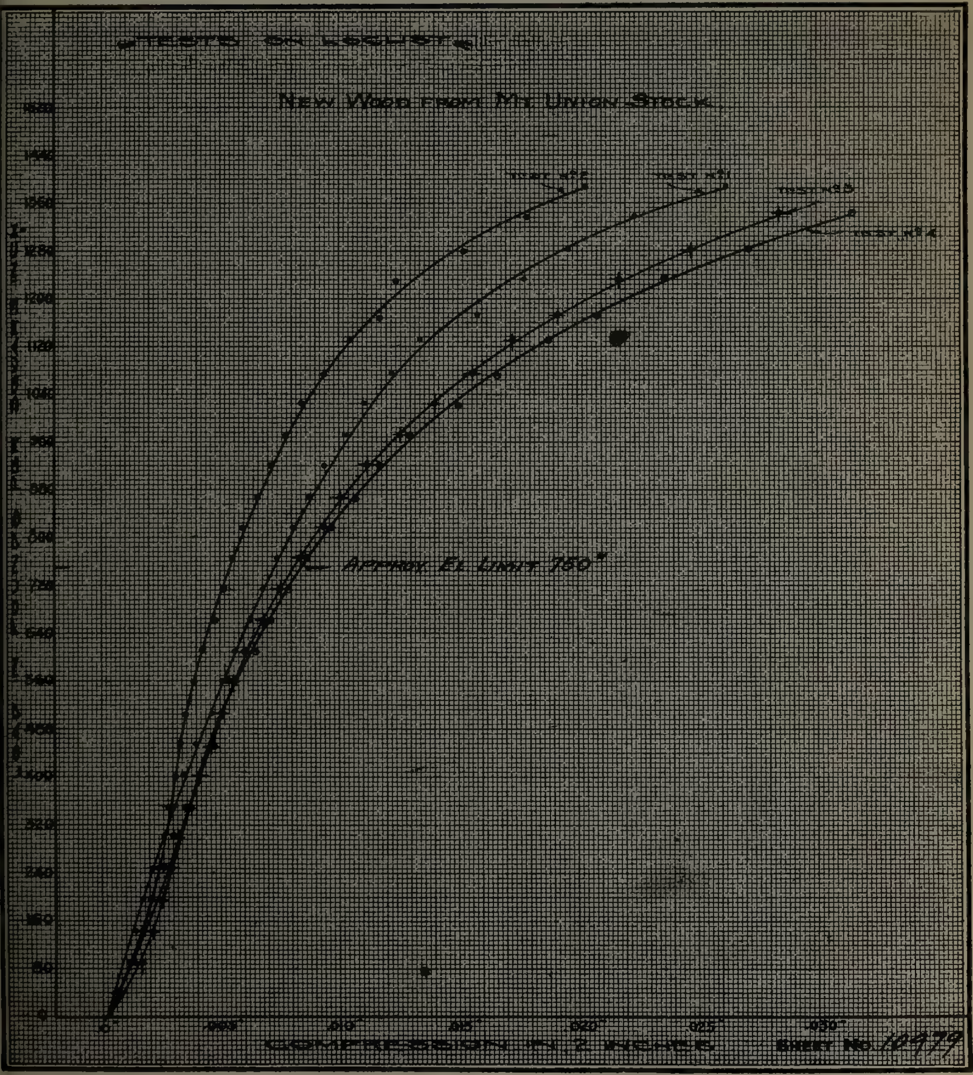


TESTS OF TIE-PLATES OF DIFFERENT THICKNESSES AND SIZES.



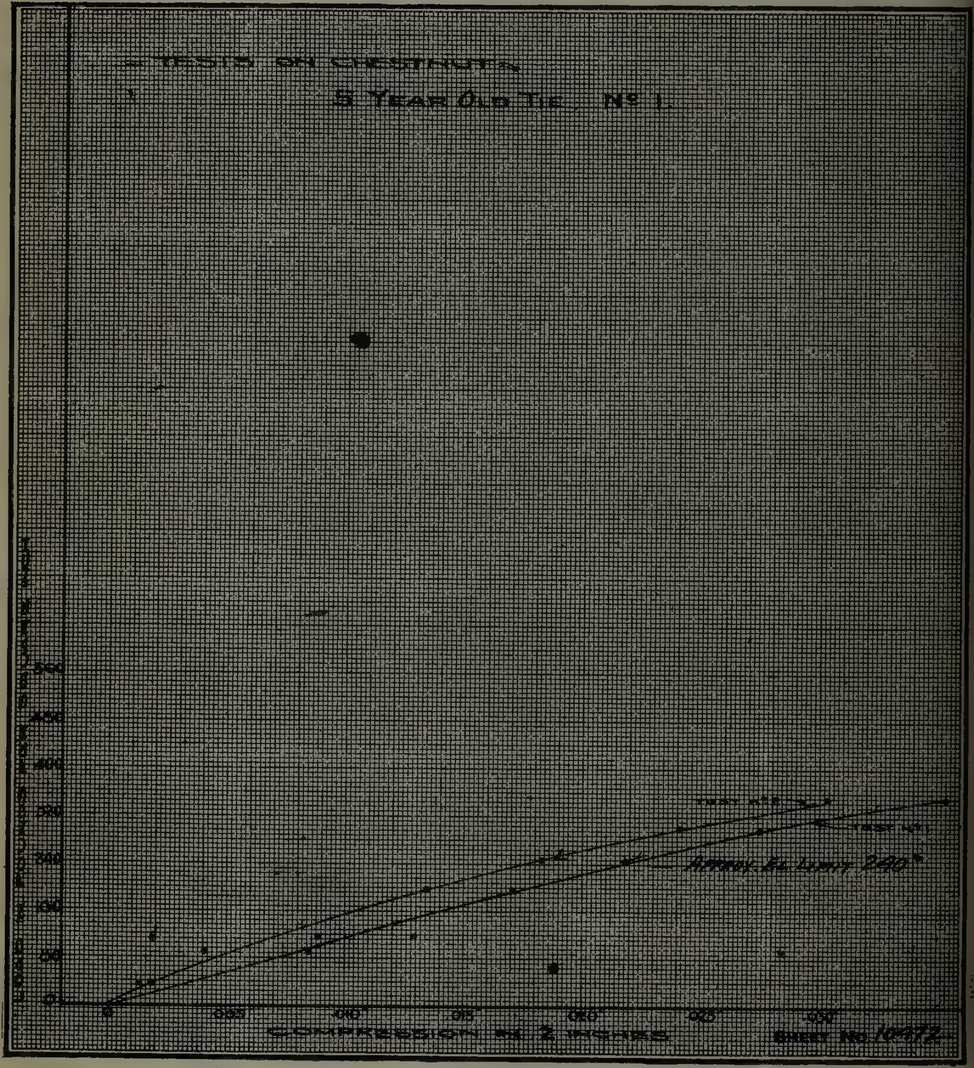
Tests of Tie-Plates of Different Thicknesses and Sizes.

September, 1915.



Compression Tests of Wood.

September, 1915.



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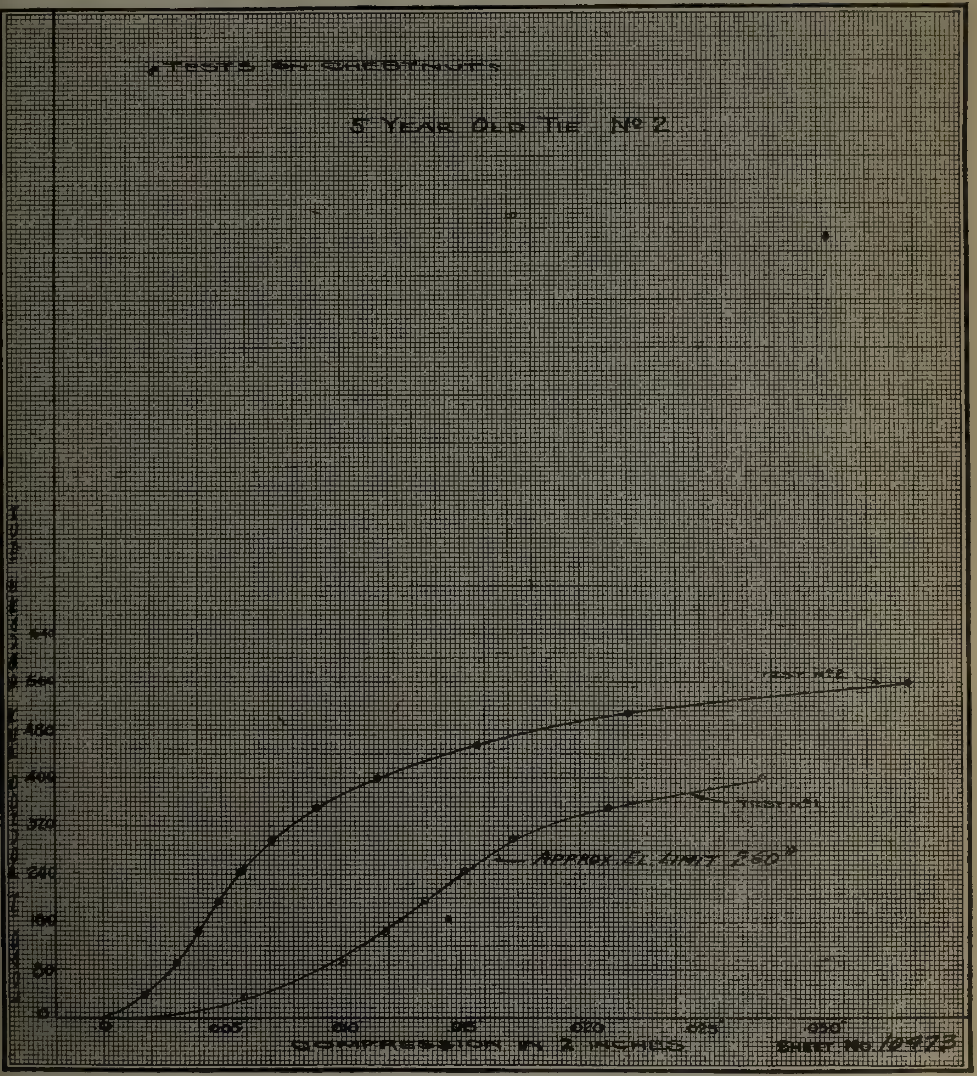
September, 1915.



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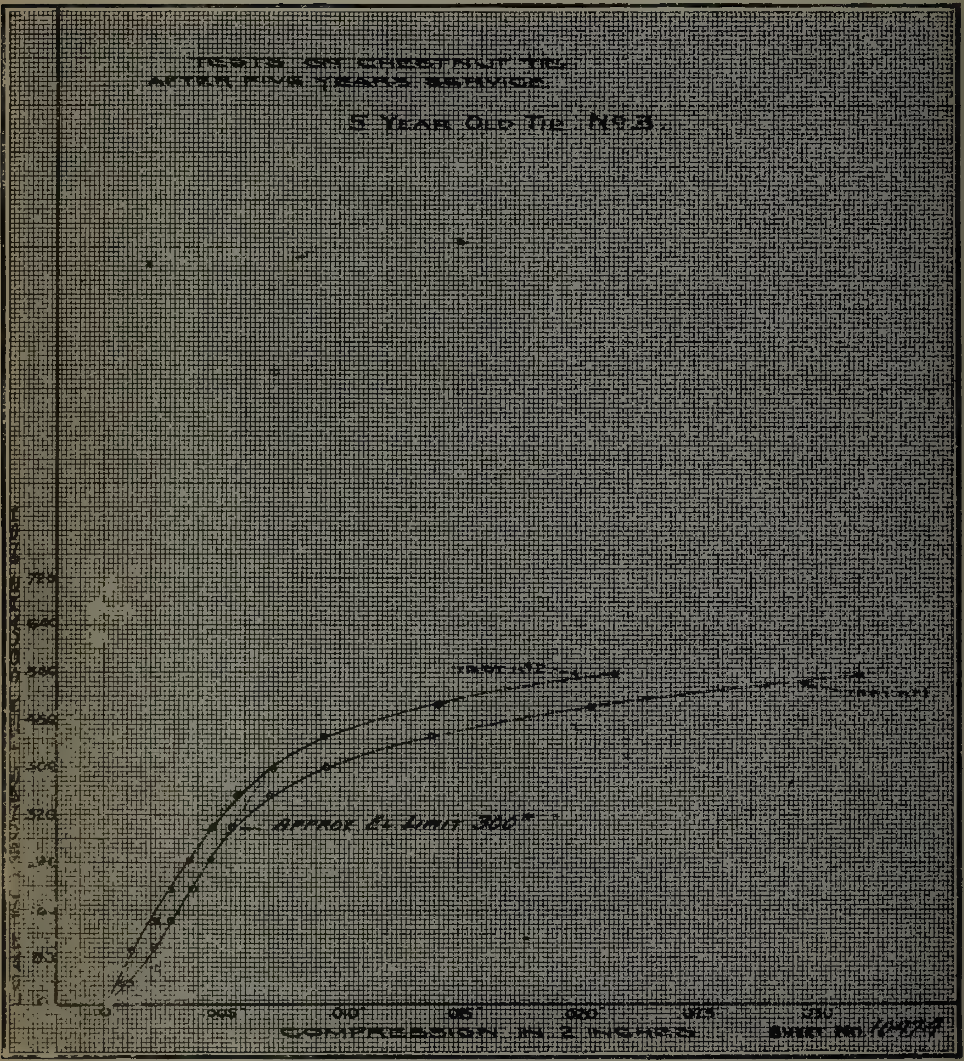
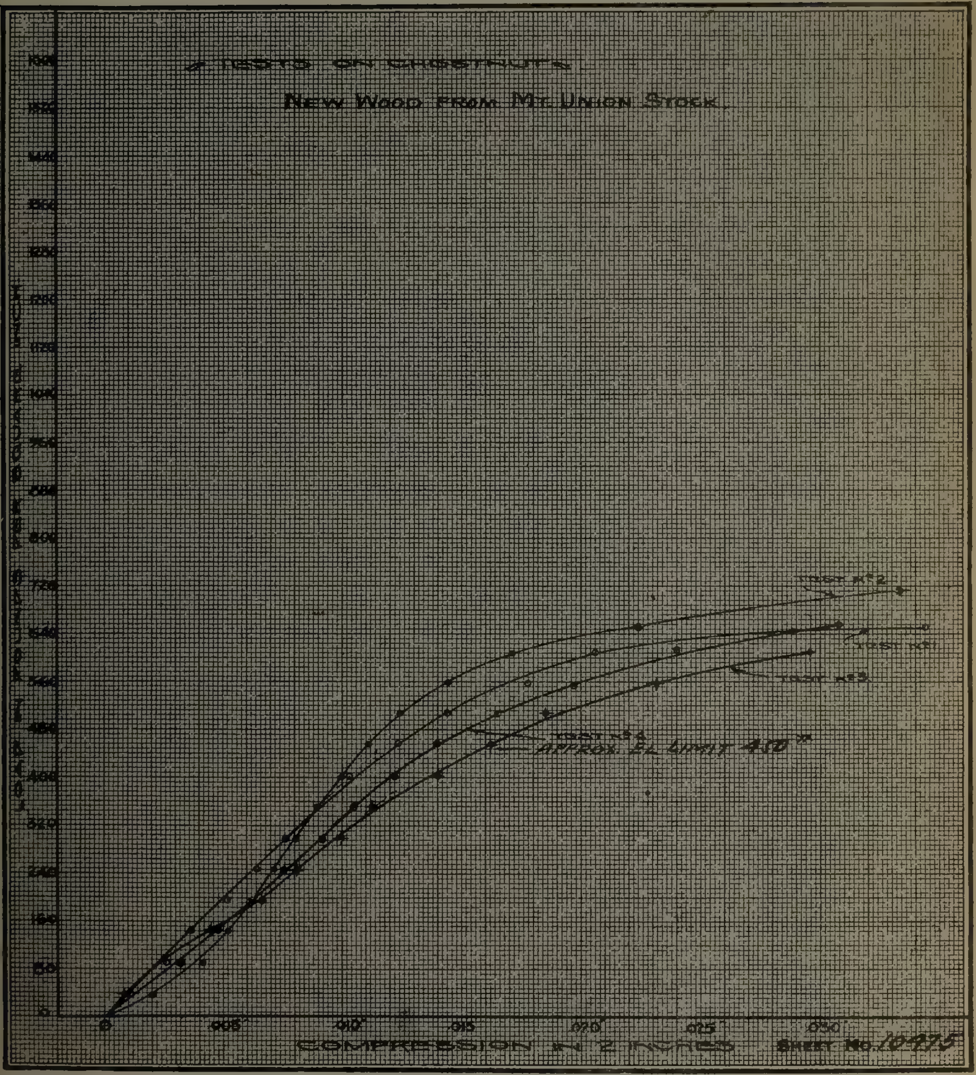
September, 1915.

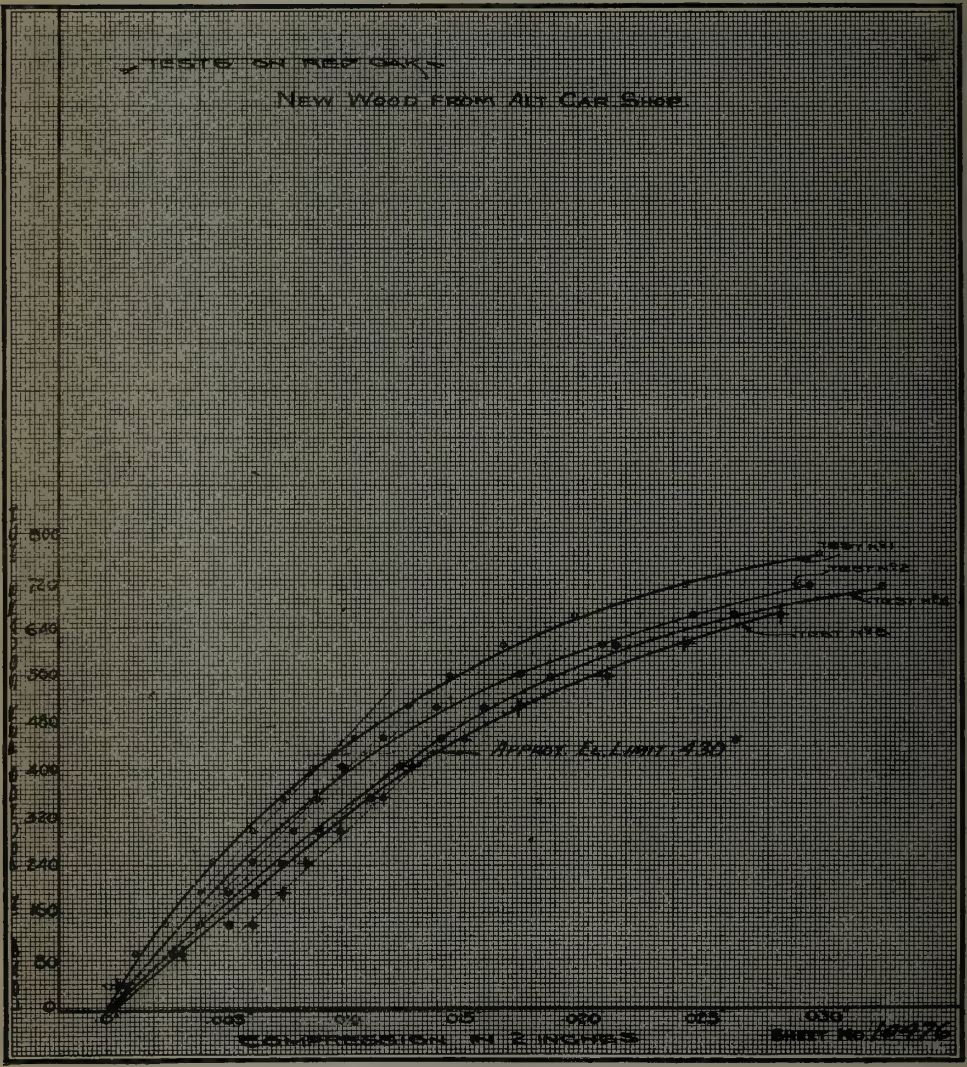


Compression Tests of Wood.

September, 1915.

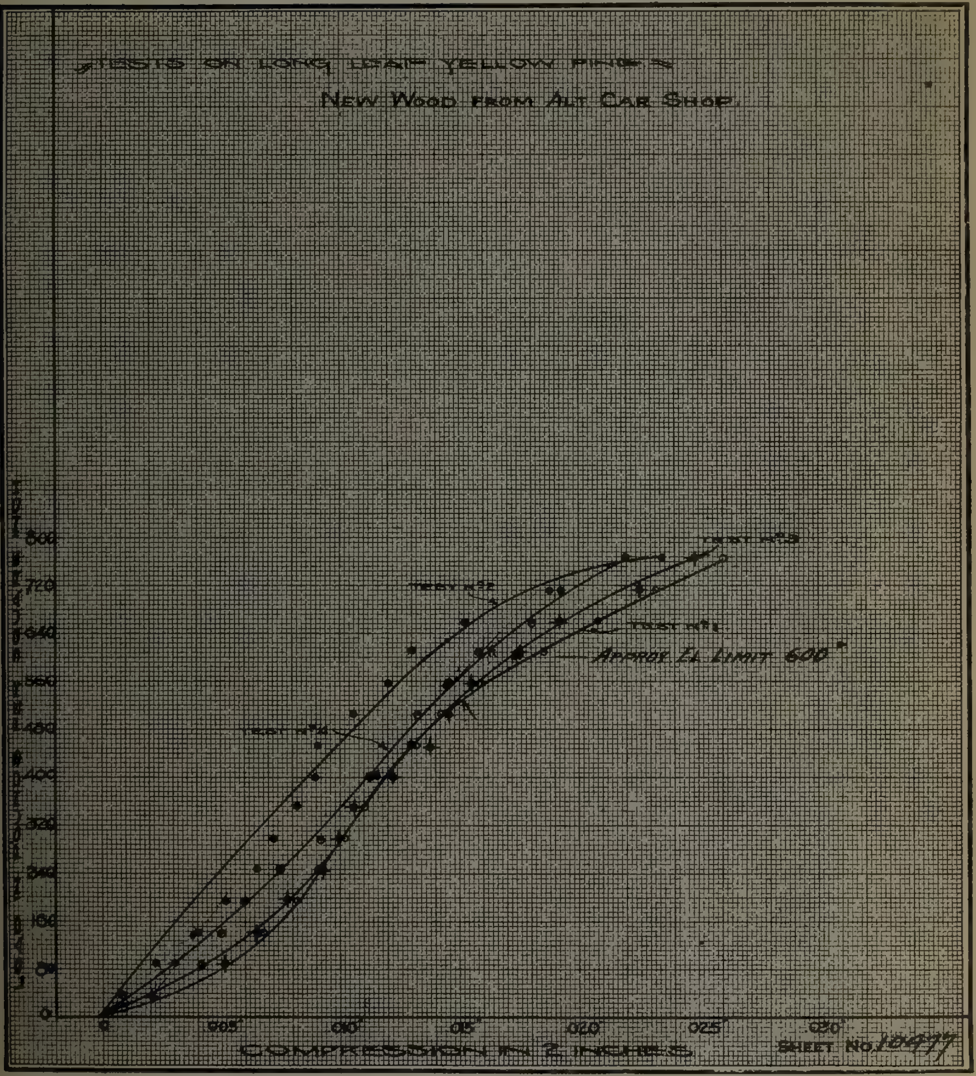


Compression Tests of Wood.

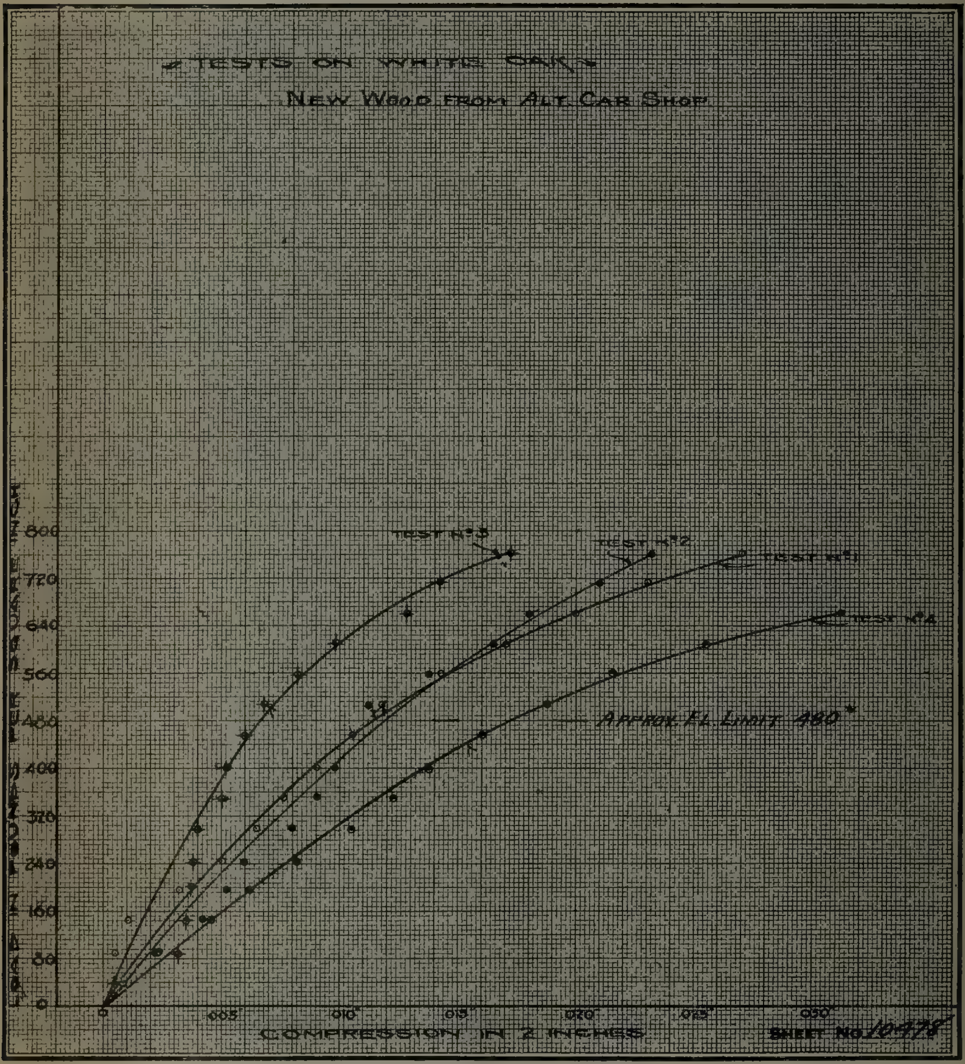


COMPRESSION TESTS OF WOOD.

September, 1915.



Compression Tests of Wood.



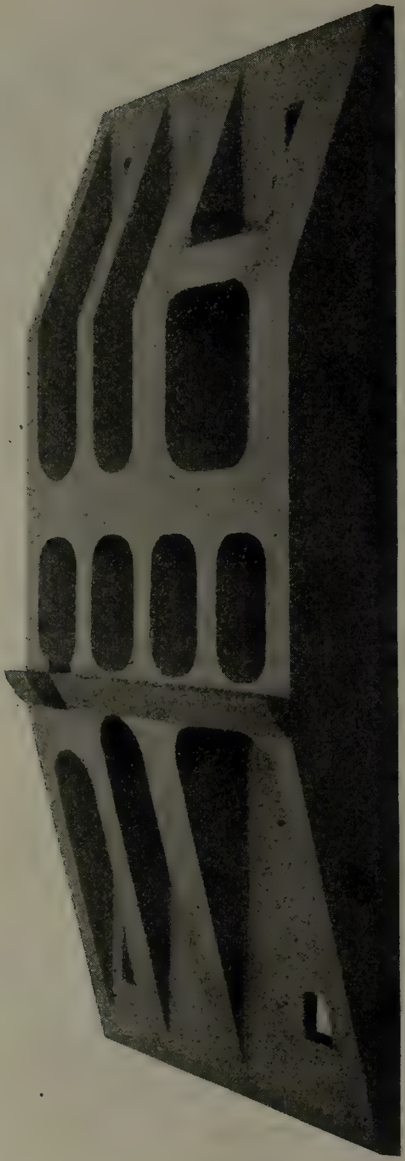
Compression Tests of Wood.

CRUSHING STRENGTH AND ESTIMATED LIFE OF UNTREATED AND TREATED CROSS-TIES.

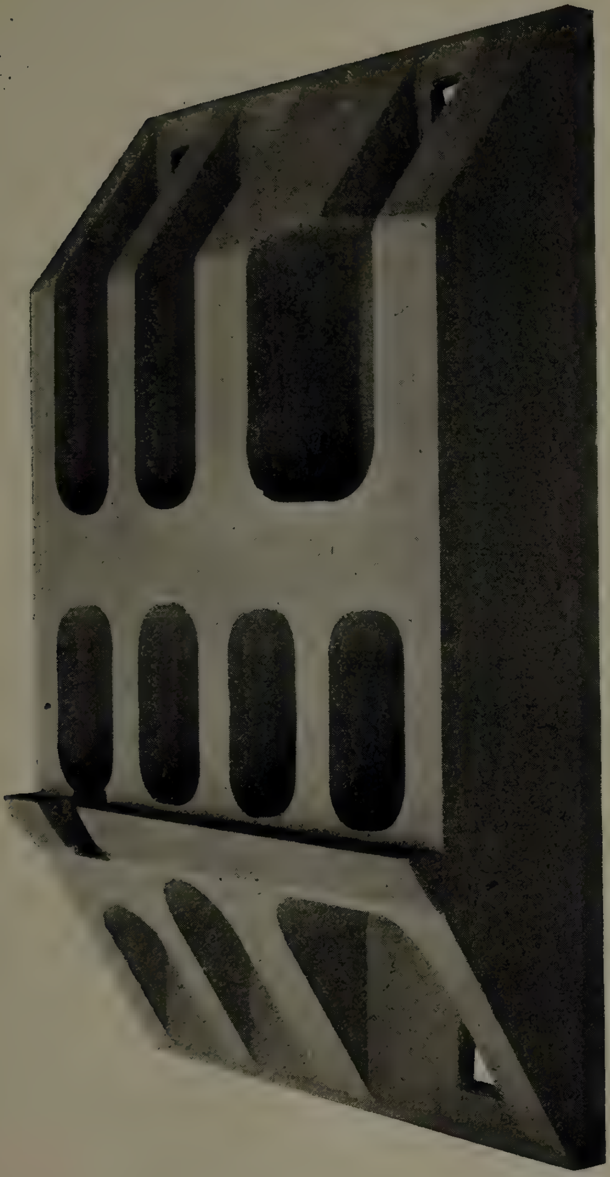
Kind of Wood	Fibre Stress at Elastic Limit Lbs.per Sq.In.	Per Cent of Honey Locust	Estimated Life (all Ties Properly Tie Plated)		
			Untreated	Treated with 10 Lbs.Creosote per Cubic Foot	Treated with 0.5 Pounds Zinc Chloride per Cubic Foot.
Honey Locust	1500 - 1600	100			
*Black Locust	1400	94	20 years	-----	-----
Hickory	1000 - 1050	66			
*White Oak	850 - 970	57	8		
*Red Oak	775 - 820	52	4	20 years	12 years
*Hard Maple	700 - 700	47	4	18	12
*Beech	600	40	4	20	12
Sassafras	500	33			
Hackberry	500	33			
*Soft Maple	500	33			
*Black Gum	500 - 500	33	3	16	11
*Longleaf (Loblolly)	500 - 500	33	7 (3)	20 (15)	(10)
*Cypress (Cedar)	500 - 550	33	10 (11)		
*Walnut	500	33			
*Birch	450	30			
*Red Gum	450	30	3	16	11
*Cherry	450	30			
Elm	450	30			
Sycamore	425 - 430	28			
*Chestnut	400	27	7	14	11
Ash	400 - 567	27			
Shortleaf Pine	400 - 400	27			
Mulberry	400	27			
Butternut	275	18			

*Commonly used on P.R.R.
Life figures obtained from Forest Service - Bulletin No. 118.
Strength figures obtained from Forest Service - Circular No. 213.

SHEET NO. 10060



Ribbed Tie-Plate, 16" by 7".



RIBBED TIE-PLATE, 10¾" BY 7".

within the figures above, the approximate thickness of plate can be determined.

The question of hard or soft wooden ties and the probable effect of decay are factors just as important as the consideration of the size of the tie-plates. This is apparent from the small margin between the load which the tie receives and the load which it is able to sustain within the elastic limit, and therefore it would seem as though these other factors should be given equal consideration with the question of the thickness of the tie-plate or its size before drawing any final conclusions as to the thickness and size of tie-plate which should be used. The low elastic limit for certain of the woods seem to indicate clearly the undesirability of purchasing these for tie purposes.

Yours truly,
(Signed) C. D. Young,
Engineer of Tests.

TESTS TO ASCERTAIN PROPORTION OF LOAD ON RAIL TRANSMITTED TO EACH TIE.

September 14, 1914.

Mr. W. G. Coughlin,
Engineer Maintenance of Way.

Dear Sir:

I enclose you herewith print from Test Department Sheet No. 9462, showing testing apparatus which we have designed in accordance with conversation which your Committee on Tie-Plates had with our Engineer of Tests on September 3rd, and in accordance with instructions received from the General Manager dated September 8th.

Kindly advise if you have any suggestions to make as to this arrangement for taking the vertical load which is applied to the rail when the equipment is passing over same.

You will note from the blueprint that three balls are set in a plate which rests upon the tie and upon these balls is placed a piece of soft steel upon which the impressions are made. This piece of soft steel being removed between tests to take readings and replaced with a fresh plate by means of a wedge which gives a sufficient clearance when removed to take out the plate. When the apparatus is set up in the track a filling piece is placed between the base of the tie-plate which sets on the tie and wedge to properly secure the apparatus in the track when not taking readings. This piece is marked on the drawing as "dummy block." Above the wedge is a portion of a standard tie-plate machined with the proper taper and size to fit in a rectangular frame which will prevent any movement of this plate, either vertically or crosswise of the tie.

Will you kindly let me have your comments or criticisms of this apparatus promptly, in order not to delay the work of making the apparatus?

Yours truly,
(Signed) J. T. Wallis,
General Supt. Motive Power.

LOAD SUSTAINED BY TIE-PLATES.

The Pennsylvania Railroad Company Test Department,
Report No. 15-12.

Altoona, Pa., February 24, 1915.

Mr. J. T. Wallis,
General Superintendent Motive Power.

Dear Sir:

In accordance with instructions contained in your memorandum of September 11, 1914, desk 1, attached to communication from Mr. S. C. Long, General Manager, dated September 8, 1914, tests have been made to determine the load sustained by tie-plates in track. This information was desired by the Committee on Screw-Spike Test covering tie-plates on tangent track, on a curve where a speed of 70 miles per hour is allowed and on a sharp curve off main line track.

DESCRIPTION OF APPARATUS.

2. The recording apparatus used in these tests consists of a steel plate, on which rests three 1-inch hardened steel balls. The tie-plate fits inside of this plate and is clamped to the rail on both sides. This tie-plate is tapered on the bottom to fit a wedge which is used to provide sufficient clearance between the top of the apparatus and the bottom of the rail. A soft steel plate, called the "Impression Plate," is inserted below the wedge and rests on the top of the steel balls. The load on the rail transmitted through the tie-plate, wedge and impression plate, causes the hardened balls to give impressions in the soft steel plate, the area of the impressions obtained in the steel plate being a measure of the load applied. Twenty of these devices were provided, a sketch of which is shown on sheet No. 9737.

3. When the apparatus is in place under the rail it is necessary that the ties be lowered 3 inches below the usual location. A 3-inch filling piece placed on the other end of tie and securely fastened to the rail and tie served to keep the opposite rail at the proper elevation. In order that the ties would have a proper foundation, a period of from one to four weeks elapsed after the ties were lowered before any tests were made over the track. During this interval the track was tamped daily and kept in first-class condition.

LOCATION OF TEST TRACK.

4. The track selected for making these tests was on the tangent section of No. 2 track East of Tipton, on the 2° curve of No. 2 track East of Tipton and 6° curve of No. 1 track East of "FR" Tower on the Middle Division. The track at these three locations is rock ballasted and laid with 100-lb. rails. The load was determined on one rail of the tangent track, on the outside rail of the 2° curve, which has an elevation of 4 inches, and on the inside rail of the 6° curve. The elevation of the outside rail on this curve is 6 inches. The apparatus was installed on the 2° curve approximately 300 feet from the point of curvature, and on the 6° curve approximately 500 feet from the point of curvature.

5. Most of the tests were run in November, 1914, and before the roadbed was frozen. Additional tests were run on the tangent track in February, 1915, after the roadbed was frozen.

METHOD OF CONDUCTING TESTS.

6. The recording devices were placed in the track to determine the load sustained by the tie-plates under two conditions of loading, as follows:

(a) Load Supported on Alternate Ties.—In this method every other tie along one rail was equipped with a recording apparatus. The intermediate ties were not tamped solid, and in this way practically the entire load on one rail was supported on the recording ties, which were spaced about 40 inches apart, the length of the track being approximately 66 ft.

(b) Load Supported on Consecutive Ties.—In this method the twenty devices were installed on consecutive ties along one rail of the track; these ties were tamped solid so that each tie would support its proportionate part of the load. The ties were spaced about 20 inches apart. The length of the test track was approximately 33 ft.

7. The impression plates used in the tests were of uniform hardness and cut from ½-inch boiler steel. Samples of these plates were tested in the laboratory under static loads of from 500 to 50,000 lbs. applied to a 1-inch steel ball. The corresponding diameters of the impressions obtained in these tests were plotted against the load applied; the resulting curve is shown on sheet No. 9560.

8. In the road tests the load transmitted by each tie-plate was obtained by measuring the diameter of each of the three holes made in the impression plates by the steel balls. The load represented by each impression was taken from sheet No. 9560, the total load on the plate being the sum of the three individual loads.

9. Tests were made with class D16, E6s, K2sa and L1s locomotives run over the test track at speeds of from 5 to 70 miles per hour. Additional tests were made with a class H-21 car empty, class H-21 car loaded and a class H-21 car having a 2½-inch flat spot on the front pair of wheels. The tests with these cars were made by allowing them to drift over the test track at various speeds. The wheel arrangement of the locomotives and the weights of the locomotives and cars is shown on sheet No. 9738. Some additional tests were made with the class E6s and K2s locomotives without the tender, in order to determine whether in this condition the impressions would be materially different than those obtained when the locomotive was run with the tender. Tests were also made with the class L1s locomotive hauling the loaded class H-21 car with and without the flat spot in the wheels, and also with the class L1s locomotive hauling a loaded freight train. In all tests the throttle was closed during the passage of the locomotive over the test track, except that one test was made with the class D16 locomotive using steam on the 2-degree curve. The speed at which the locomotive or cars were run over the test track was obtained by taking the time required to cover a measured section just previous to the entrance to the test track.

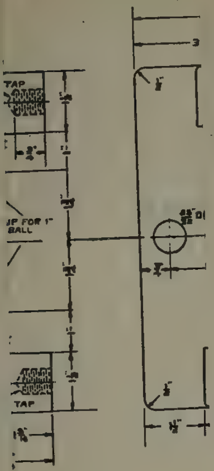
RESULTS OF TESTS.

10. The results of the tests may be grouped under two heads:
(a) Recording apparatus placed on alternate ties, and
(b) Recording apparatus placed on consecutive ties.

RECORDING APPARATUS PLACED ON ALTERNATE TIES.

11. The load registered on each recording tie, calculated from the impressions made in the soft steel plates, is shown graphically on the following representative sheets:
Sheets Nos. 9740 and 9742, inclusive, tests made on tangent track.
Sheets Nos. 9748 and 9750, inclusive, tests made on the 2-degree curve.
Sheets Nos. 9756 and 9758, inclusive, tests made on the 6-degree curve.

12. The maximum and average load obtained on the tests, plotted against the speed at which the tests were run, are shown on sheets Nos. 9760 to 9764, inclusive, you will note that on the tangent track and on the 2-degree curve the load obtained increases with the speed. This increase



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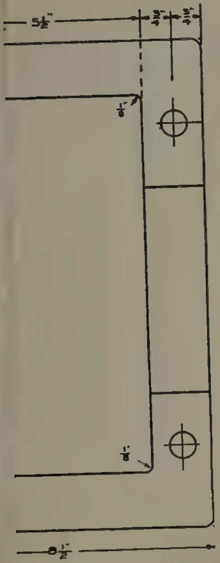

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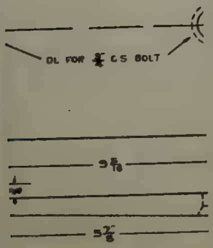


PLATE, M W PLAN 61300; D

(a) Load Supported on Alternate Ties.—In this method every other tie along one rail was equipped with a recording apparatus. The intermediate ties were not tamped solid, and in this way practically the entire load on one rail was supported on the recording ties, which were spaced about 40 inches apart, the length of the track being approximately 66 ft.

(b) Load Supported on Consecutive Ties.—In this method the twenty devices were installed on consecutive ties along one rail of the track; these ties were tamped solid so that each tie would support its proportionate part of the load. The ties were spaced about 20 inches apart. The length of the test track was approximately 33 ft.

7. The impression plates used in the tests were of uniform hardness and cut from ½-inch boiler steel. Samples of these plates were tested in the laboratory under static loads of from 500 to 50,000 lbs. applied to a 1-inch steel ball. The corresponding diameters of the impressions obtained in these tests were plotted against the load applied; the resulting curve is shown on sheet No. 9560.

8. In the road tests the load transmitted by each tie-plate was obtained by measuring the diameter of each of the three holes made in the impression plates by the steel balls. The load represented by each impression was taken from sheet No. 9560, the total load on the plate being the sum of the three individual loads.

9. Tests were made with class D16, E6s, K2sa and L1s locomotives run over the test track at speeds of from 5 to 70 miles per hour. Additional tests were made with a class H-21 car empty, class H-21 car loaded and a class H-21 car having a 2½-inch flat spot on the front pair of wheels. The tests with these cars were made by allowing them to drift over the test track at various speeds. The wheel arrangement of the locomotives and the weights of the locomotives and cars is shown on sheet No. 9738. Some additional tests were made with the class E6s and K2s locomotives without the tender, in order to determine whether in this condition the impressions would be materially different than those obtained when the locomotive was run with the tender. Tests were also made with the class L1s locomotive hauling the loaded class H-21 car with and without the flat spot in the wheels, and also with the class L1s locomotive hauling a loaded freight train. In all tests the throttle was closed during the passage of the locomotive over the test track, except that one test was made with the class D16 locomotive using steam on the 2-degree curve. The speed at which the locomotive or cars were run over the test track was obtained by taking the time required to cover a measured section just previous to the entrance to the test track.

RESULTS OF TESTS.

10. The results of the tests may be grouped under two heads:

(a) Recording apparatus placed on alternate ties, and

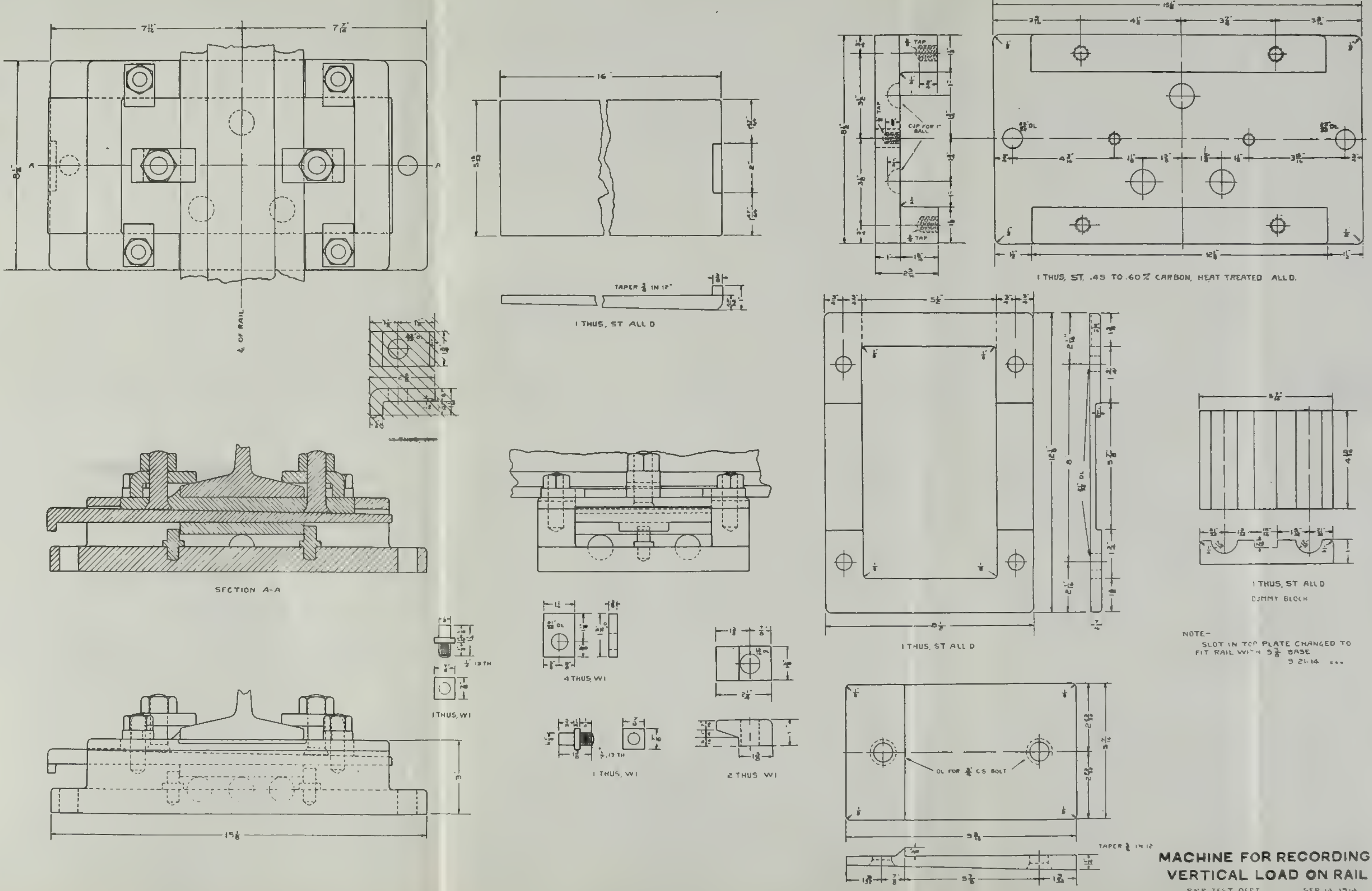
(b) Recording apparatus placed on consecutive ties.

RECORDING APPARATUS PLACED ON ALTERNATE TIES.

11. The load registered on each recording tie, calculated from the impressions made in the soft steel plates, is shown graphically on the following representative sheets:

Sheets Nos. 9740 and 9742, inclusive, tests made on tangent track.
Sheets Nos. 9748 and 9750, inclusive, tests made on the 2-degree curve.
Sheets Nos. 9756 and 9758, inclusive, tests made on the 6-degree curve.

12. The maximum and average load obtained on the tests, plotted against the speed at which the tests were run, are shown on sheets Nos. 9760 to 9764, inclusive, you will note that on the tangent track and on the 2-degree curve the load obtained increases with the speed. This increase



NOTE-
SLOT IN TOP PLATE CHANGED TO
FIT RAIL WITH 5 3/8 BASE
9 21-14

MACHINE FOR RECORDING VERTICAL LOAD ON RAIL

P.R.R. TEST DEPT SEP 14 1914

SHEET No 9462

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is more rapid on the tests made on the outside rail of the 2-degree curve than those made on the tangent track.

13. Comparing the maximum curve, it will be observed that below a speed of 40 miles per hour the loads obtained on the 2-degree curve are not materially greater than those obtained on the tangent track. Above this speed the loads shown for the 2-degree curve increase more rapidly with the speed than those for the tangent track.

14. On the 6-degree curve the loads recorded decrease as the speed of the locomotive is increased. This would be expected, inasmuch as the recording apparatus was placed on the inside of the curve, and there is no doubt that if records had been taken on the outside rail a corresponding increase in load with the speed would have been obtained.

Locomotive running without tender.

15. Some tests were made with class E6s and K2sa locomotives to determine the load recorded without the tender attached to the locomotive. In such cases the loads were usually less than those recorded when the tender was attached to the locomotive, but the difference with the two conditions were not of sufficient magnitude to warrant making a full series of tests without the tender attached to the locomotive.

Locomotive using steam over the test track.

16. The usual procedure in conducting the tests was to operate the locomotive over the test track with the throttle closed, in order that there would be but a slight change in the speed of the locomotive over the test section. One test, however, was made on the 2-degree curve with the class D16 locomotive with the throttle open. The maximum and average load recorded in this case was higher than when the locomotive was run with the throttle closed. The difference in the results obtained with the two conditions of locomotive operation, were no greater than we found between other tests with all conditions presumably similar, and, in our opinion, was not due to the different manner in which the D16 locomotive was operated on the two tests.

Class H21 cars.

17. Sheets Nos. 9761 and 9763 show graphically the maximum and average load recorded with the class H21 cars. As would be expected, the load recorded with the car having the flat spot on the wheel increases with the speed at which the car was moved, but at the low speeds is about the same as the H21 car without the flat spot. The table on sheet No. 9765, p. 215, shows the maximum, minimum and average loads obtained on all the tests with these cars. The loads obtained from the empty car are about the same on the tangent and the 2-degree curve. Those for the loaded cars are slightly less on the 2-degree curve than they were on the tangent track, probably due to the elevation of the outer rail and the comparatively low speed at which the tests were made, which would tend to bring the greater part of the load on the inside rail.

RECORDS TAKEN ON CONSECUTIVE TIES.

18. The load recorded on each tie for 20 consecutive ties for locomotives, classes L1s, K2sa, E6s and D16, are shown graphically on the following representative sheets:

Sheets Nos. 9767 and 9769, inclusive, tests made on tangent track.
Sheets Nos. 9772 and 9775, inclusive, tests made on 2-degree curve.
Sheets Nos. 9777 and 9779, inclusive, tests made on 6-degree curve.

19. With the above arrangement of recording device the loads obtained are from 10 to 20 per cent. less than those found when the apparatus was placed on alternate ties. The decrease in the load on each tie is due to the increase in the number of rail supports in a given distance.

The maximum and average load of each test, is shown graphically on sheets Nos. 9781 to 9783, inclusive. It will be observed that the load obtained increases with the speed of the locomotive on the tangent track and 2-degree curve and decreases with the speed on the 6-degree curve. The loads recorded on the 2-degree curve are about the same as those found on the tangent track up to a speed of 40 miles per hour, confirming the results obtained when the apparatus was installed on the alternate ties.

Loaded freight train hauled by class L1s locomotive.

20. Sheets Nos. 9781 to 9783, inclusive, show the results of tests made with a loaded freight train hauled by L1s locomotive, compared with those made with the class L1s locomotive run light. With the locomotive and train the maximum load obtained is from 15 to 29 per cent. greater than that shown when the locomotive is run light. Trains of from 78 to 102 cars were run over the test track, but with this variation in weights and lengths of trains there was no consistent difference in the loads obtained.

21. That the loads represented by the indentations made in the impression plates by the passing of the locomotive over the test section are increased by the subsequent movement of cars of a lighter weight per axle, is due to the fact that these lighter loads are applied dynamically due to flat wheels, oscillation of cars, etc.

TESTS RUN ON TANGENT TRACK—FROZEN ROADBED.

22. On sheets Nos. 9784 to 9787, inclusive (not shown), are shown graphically the results of the tests run with the various classes of locomotives with the roadbed in frozen condition.

23. On sheet No. 9788 is plotted the load against the speed at which the tests were run. Comparing the results on this sheet with those shown on sheet No. 9781, which were made in warm weather. It will be noted that the average load recorded on the frozen roadbed was from 15 to 25 per cent. greater than those shown in the warm weather tests.

COMPARISON OF THE RESULTS—ALTERNATE AND CONSECUTIVE TIES.

24. A summary of the results obtained on the various test tracks for the two installations of test apparatus, is shown on sheets 9789 to 9792, pp. 190-193, inclusive. You will note that for similar speeds the average recorded load is less when the apparatus was placed on consecutive ties than when it is placed on alternate ties.

25. Considering the condition of the roadbed and the spacing of the supporting ties in the two methods of applying the recording devices, we are of the opinion that the loads determined when the apparatus was placed on consecutive ties more nearly represents service conditions than when placed on alternate ties.

CONCLUSIONS.

26. The following table summarizes briefly the highest average and maximum loads obtained on the tangent track, 2-degree curve and 6-degree curve with the locomotives run light and also with a locomotive and train of freight cars.

Location of Test Track ..	*Tangent Track*	*2-Degree Curve*	*6-Degree Curve*
Equipment	*Locomotives run Light*		
Class of Locomotive	E-6s	K-2sa	K-2sa
Speed, Miles per Hour	70.8	8.5	11.1
Maximum Load—Lbs............	37,900	36,625	62,080
Class of Locomotive	L1s	K-2sa	K-2sa
Speed, Miles per Hour	5.2	42.1	11.1
Average Load—Lbs..............	20,450	19,190	37,014

Equipment	*Locomotive and Train*		
Number of Cars in Train	78	91	102
Speed, Miles per Hour	43.5	45.4	5.9
Maximum Load—Lbs.	34,625	39,450	78,745
Average Load—Lbs.	22,551	26,212	39,887

27. The table is based on the results of tests made on consecutive ties, as with this installation of test apparatus the true condition of the average track is more nearly approached than when the apparatus was installed on alternate ties.

28. The loads shown in the table are those obtained when the roadbed was unfrozen and in our opinion should be given greater consideration than those found when the roadbed was frozen, for the reason that our track structure is in the latter condition but a small percentage of the total time and by proper drainage the effects of freezing can in a large measure be overcome and further, if, in designing tie-plates, proper consideration is given to the maximum loads obtained with unfrozen roadbed the average loads obtained with frozen roadbed will be covered.

EFFECT OF TRACK CURVATURE ON TIE-PLATE LOADS.

29. From the above table the following conclusions may be drawn:

a—The design of tie-plates to meet curve conditions should be different from that on tangent track, due to the fact that a variation in the elevation of the curve has a material bearing upon the load which the tie-plate sustains, and as this elevation can only be made for a compromise speed, excessive loads will occur at other speeds.

b—Tie-plates designed for use on curves up to and including 2 degrees might be of the same class as those designed for tangent track.

c—The bearing value of tie-plates for curves of 6 degrees and over should be approximately twice that used on tangent tracks.

d—Tie-plates for curves of between 2 and 6 degrees in all probability do not need as great a bearing value as tie-plates used on 6-degree curves and over, but should have a bearing value greater than tie-plates on tangent track.

e—It would, therefore, seem that in order not to have too many designs of tie-plates the dividing line for change in design from tangent to curved track would be between the 2- and 6-degree curve and that the bearing value of the two designs of tie-plates should be approximately 1.6 to one.

RATIO OF STATIC TO DYNAMIC LOADS ON TIE-PLATES.

30. The following tabulation shows the maximum static load which was placed on the tie-plates at each of the locations of the test apparatus and also the maximum load which was recorded in the impression plates.

	Maximum Loads—Lbs.		*Ratio of Static Load*
	Static.	*Dynamic.*	*to Dynamic Load.*
		Tangent Track.	
Locomotive and train of Loaded cars	32,750	34,625	1:1.06
Locomotive Light	34,000	37,900	1:1.11
		2-Degree Curve.	
Locomotive and train of Loaded Cars	32,750	39,450	1:1.20
Locomotive Light	34,000	35,625	1:1.05
		6-Degree Curve.	
Locomotive and train of Loaded Cars	32,950	78,745	1:2.39
Locomotive Light	34,000	62,080	1:1.83

31. From the above table it will be observed that the maximum dynamic load on the tie-plates when the locomotives are run light is for tangent track and the 2-degree curve less than 1.2 times the static load, and on the 6-degree curve the dynamic load is 1.83 times the maximum static load.

32. For a locomotive and train of loaded cars the dynamic load recorded on the tangent and 2-degree curve does not exceed 1.2 times the maximum static load, on the 6-degree curve, however, the maximum dynamic load is 2.39 times the maximum static load. This latter ratio obtained on the 6-degree curve was the result found with a train of 102 cars passing over the test apparatus, during which 408 car wheels struck the plate dynamically. Therefore, we feel that the limitation of our apparatus was such that this impression is not a correct one for the maximum load which the tie-plate actually sustains, but rather has been accumulated from repeated dynamic loads and it is probable that for cars, the maximum blow which the tie-plate receives is not in excess of the blow found for a flat wheel car which was 26,364 lbs.

33. We believe that the same reasoning should apply to the observations made on tangent track and, therefore, the controlling feature in the ratio of the static to the dynamic load is the locomotive. We, therefore, feel that it is safe to assume that under the usual operating conditions the dynamic blow will not be greater than twice the static load of the locomotive.

34. It is desirable to ascertain for what load our tie-plates should be designed for use on tangent and curved track and, in reviewing the data and these conclusions, it is apparent that this load can only be a compromise between the average load which the tie-plate sustains and the maximum load. If it is desired to design the tie-plate to meet the maximum conditions, they should be designed to sustain a load for tangent track of not less than 38,000 lbs. and for a curved track somewhere between 2 and 6-degree curves of not less than 60,000 lbs. The actual maximum having been obtained on a 6-degree curve with K-2 locomotive at 11 miles per hour of 62,000 lbs. If, on the other hand, the design is based upon the average for tangent track, the figures are reduced to 20,000 lbs. and for curved track to 37,000 lbs. In our judgment, it would not be proper to design the tie-plates for the average load, due to the irregularity in tamping and that loads up to the maximum would cause permanent deformation in the tie. These figures should be the basis, however, for some compromise figure in tie-plate design which will consider all of the factors involved in the maintenance of the tie-plate and the tie, with due regard to the distribution of the load under the tie-plate and the fact that the tie-plate is to be applied on tangent or curved track. A suggested figure for the tie-plate load, if it does not involve too great an expense in tie-plate design, would seem to be in the neighborhood of 38,000 lbs. for tangent track and an increase of 60 per cent over this for curves, above the division point selected from Par. 29 (e).

RECOMMENDATIONS.

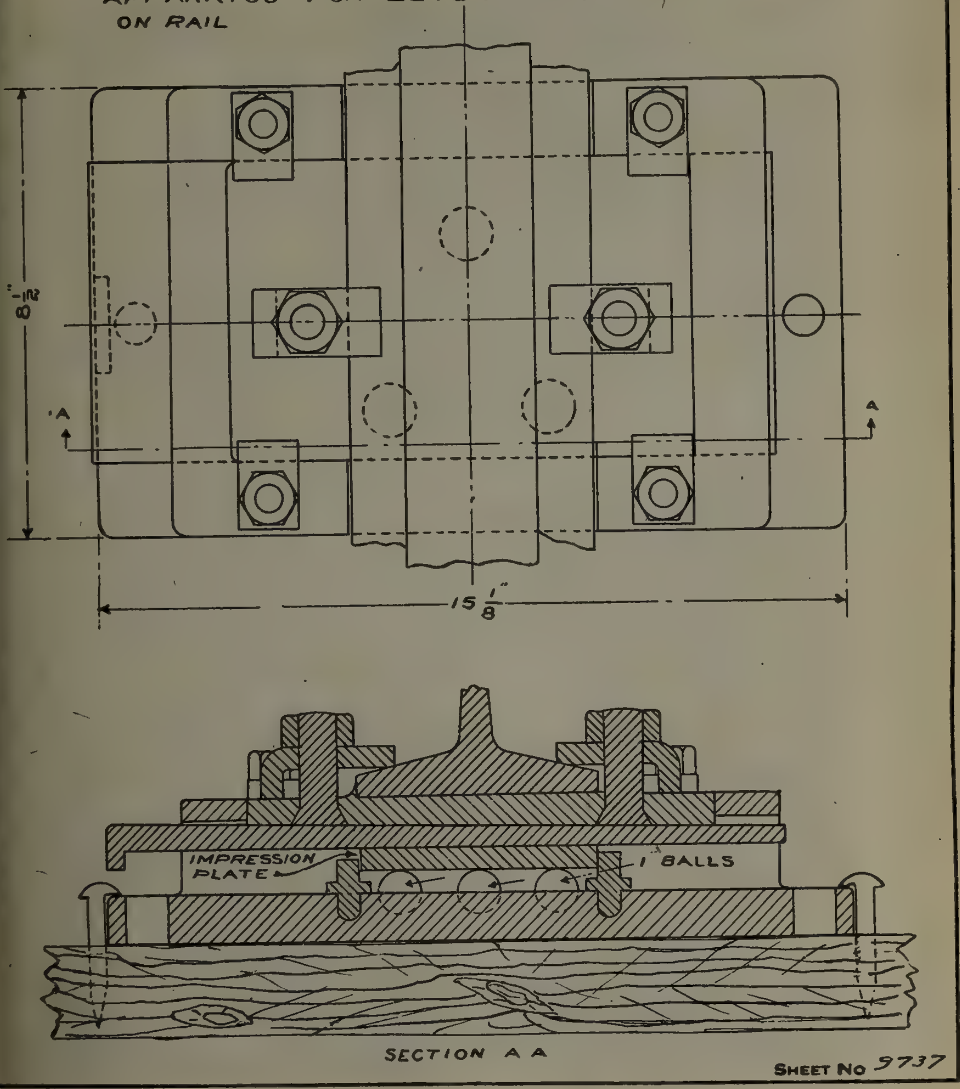
35. We have been requested to make microscopic examination of the structure of ties after they have been subjected in the laboratory to repeated application of the loads as determined in these road tests.

36. In view of the results given above, we would recommend that this report be referred to the Committee on Screw-Spike Tests and that they advise us what load they desire used for laboratory investigation of the ties and tie-plates.

(Signed) C. D. Young,
Engineer of Tests.

Report No. 15-12.
February 17, 1915.

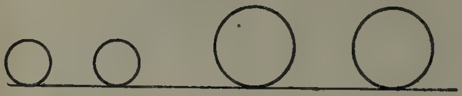
APPARATUS FOR DETERMINING VERTICAL LOAD ON RAIL



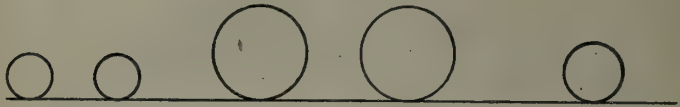
Report No. 15
February 17, 19

WHEEL ARRANGEMENTS AND WEIGHTS OF LOCOMOTIVES

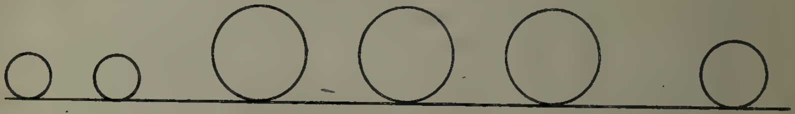
CLASS D16 LOCO



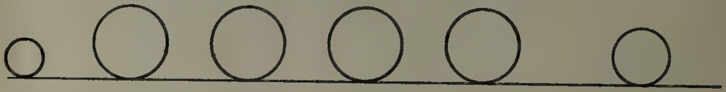
CLASS E6S. LOCO



CLASS K2SA LOCO



CLASS L1S LOCO



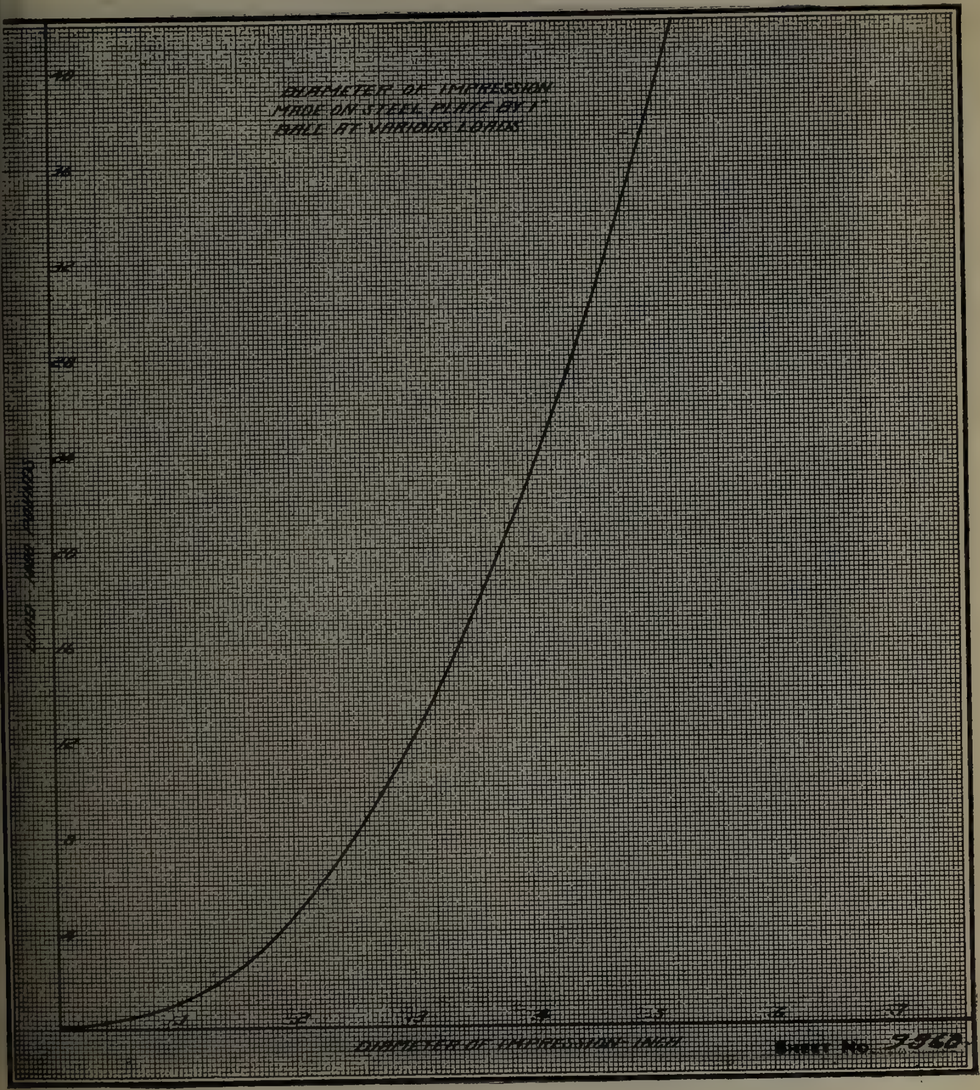
	LOCOMOTIVE NUMBERS AND CLASS					
	D16 134	E6S 272	K2SA 877	K2S 922	L1S 1904	L1S 710
ENGINE TRUCK	39750	55200	48600	50550	29200	29900
1ST PAIR DRIVERS	52700	68000	60925	57950	56850	56825
2ND. " "	46900	68070	62750	61000	56500	56600
3RD. " "			61525	39900	63200	60250
4TH. " "					65500	65900
TRAILER		32400	53600	52875	49960	51850
TOTAL	139350	243670	286900	282275	321210	321325

WEIGHT OF CARS

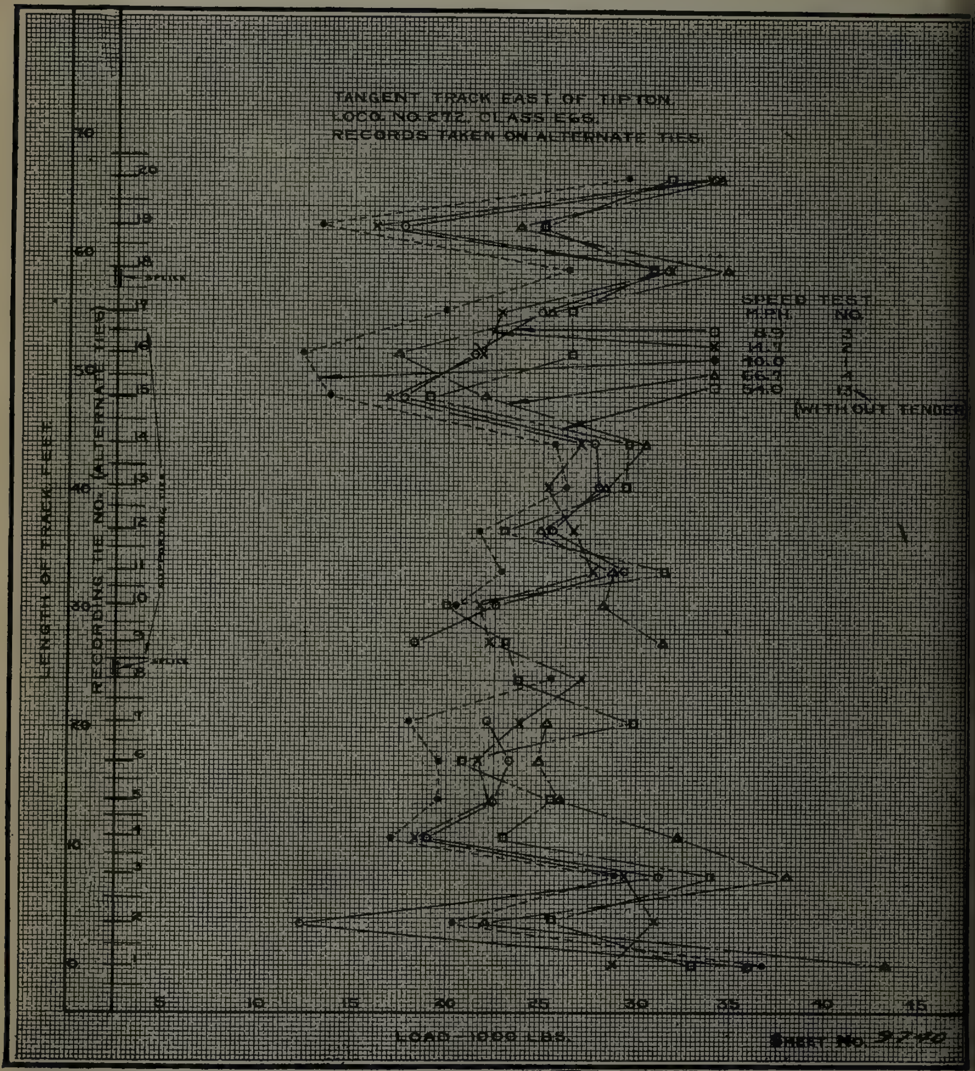
CLASS H21 EMPTY - WEIGHT = 48100#
CLASS H21 LOADED - WEIGHT = 159400#
CLASS H21 LOADED - WEIGHT = 159900# FLAT SPOT ON ONE PAIR OF WHEELS 2½ INCHES IN LENGTH

SHEET NO. 9738

Report No. 15-12.
October 12, 1914.



Report No. 15-
February 17, 191



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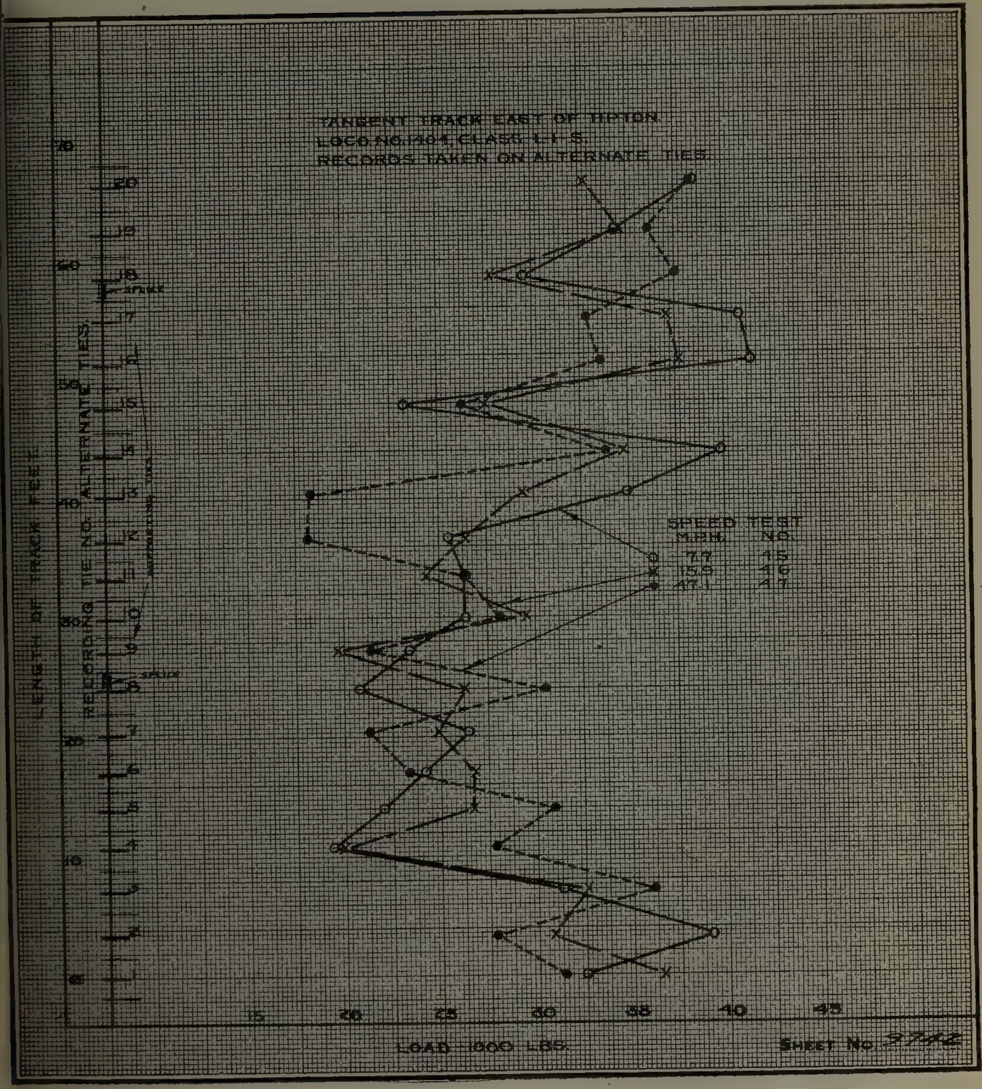
February 17, 1915.



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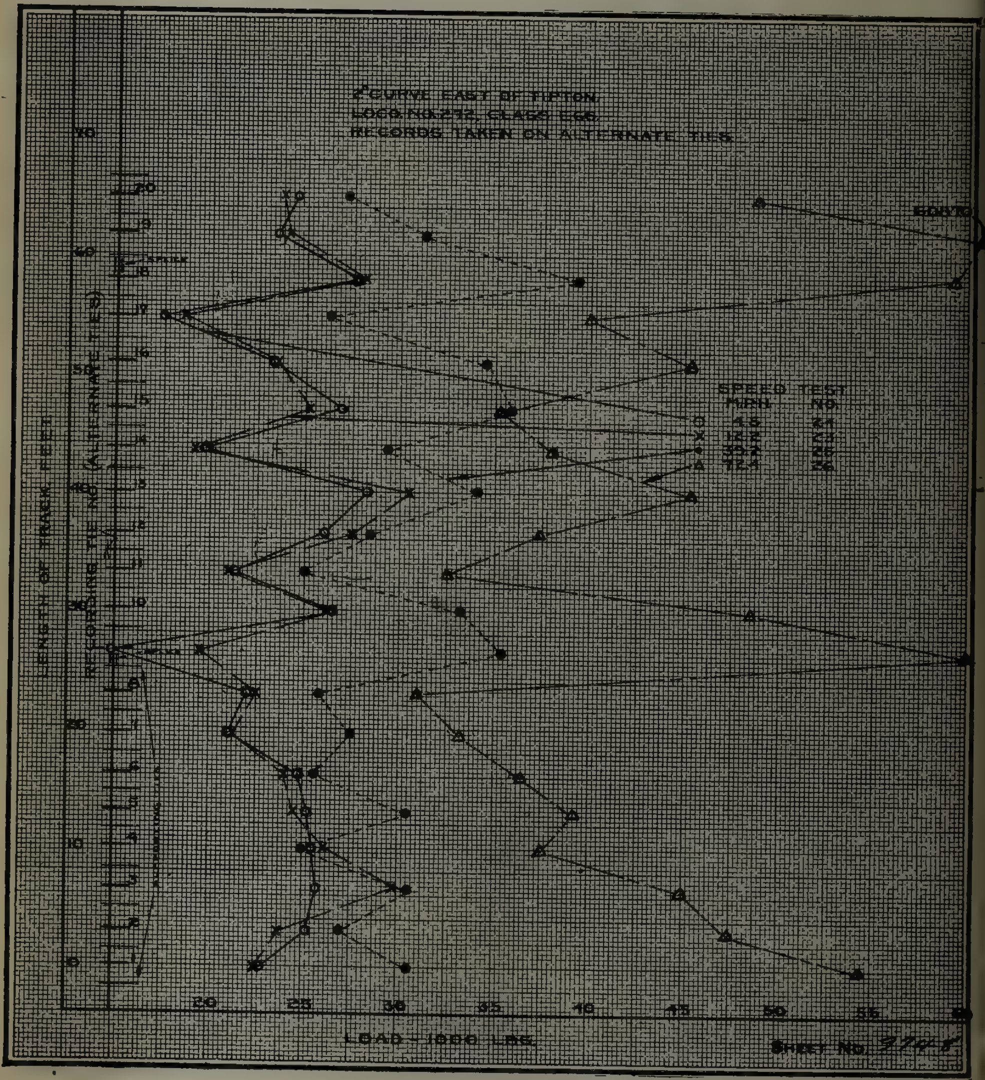
February 17, 191



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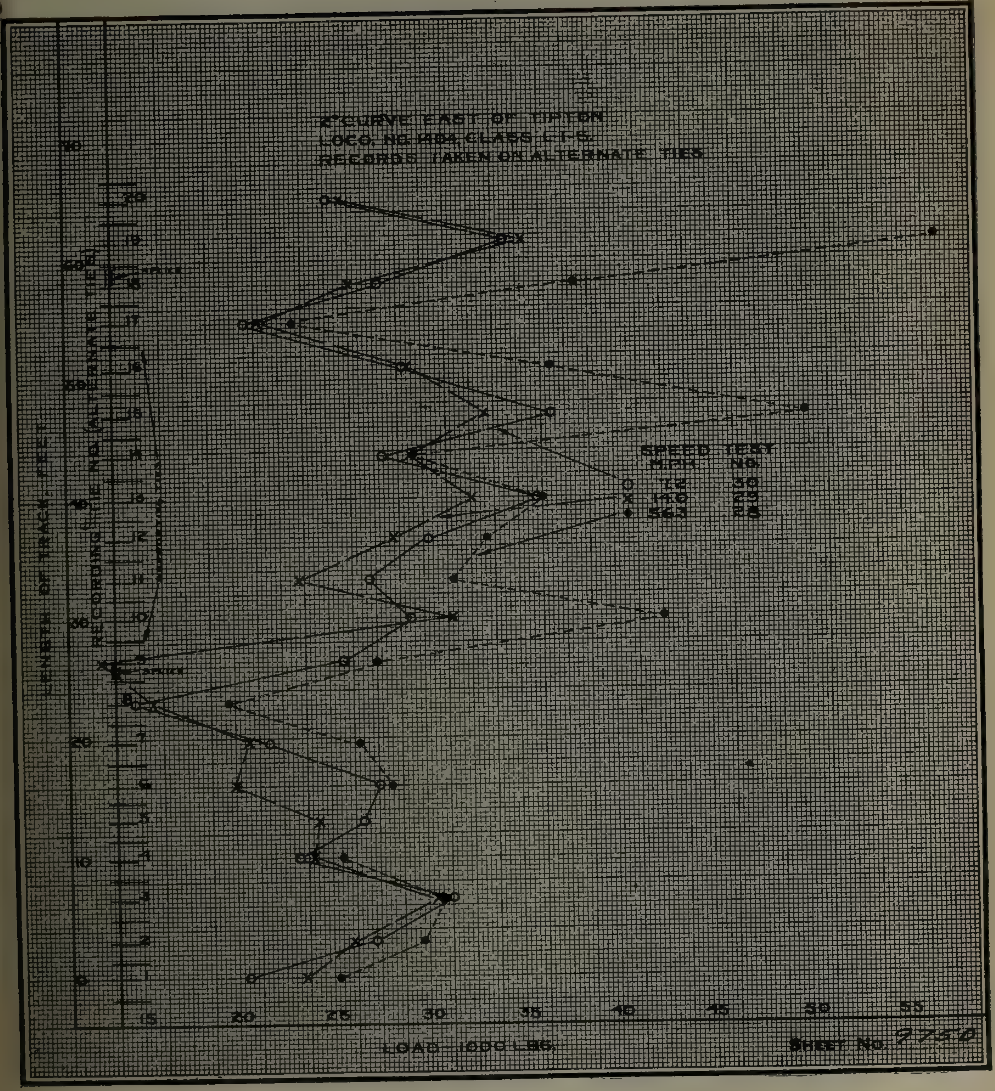
February 17, 1915.



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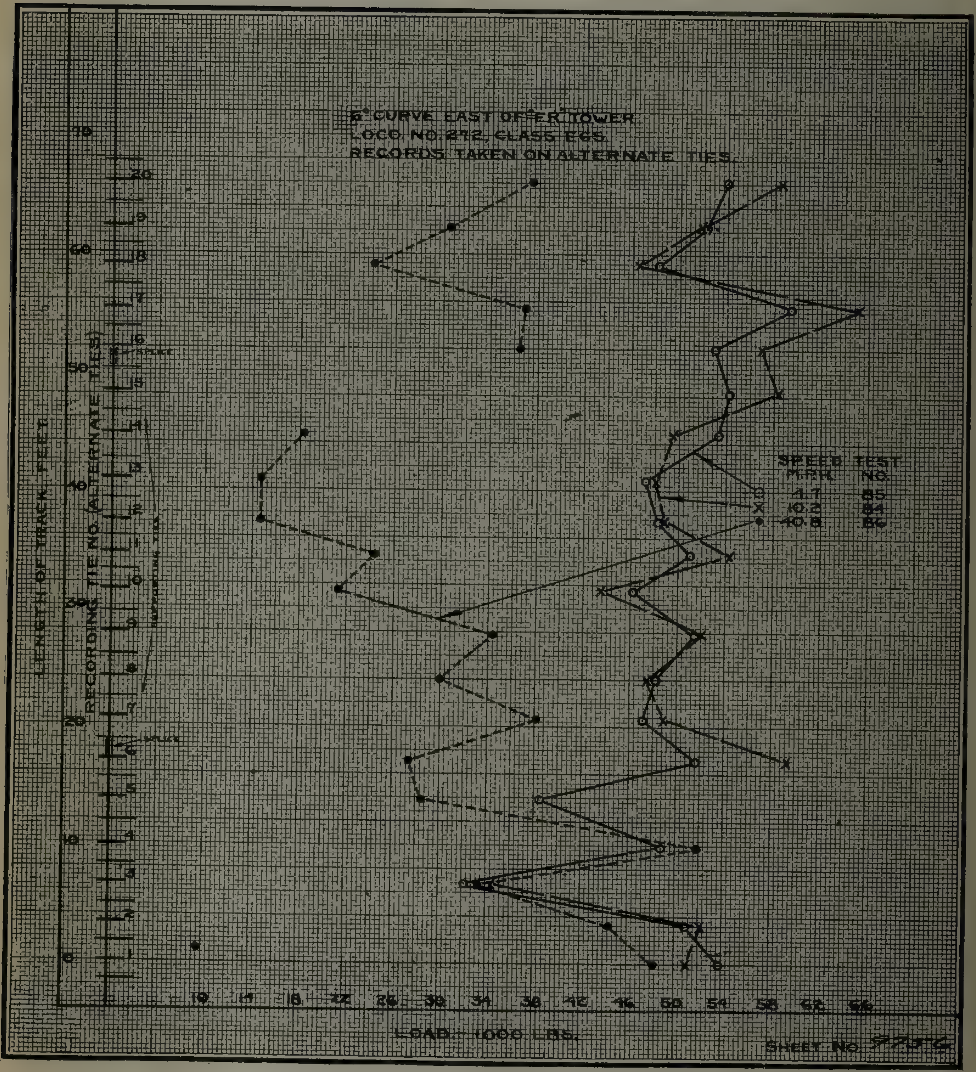
February 17, 1915.



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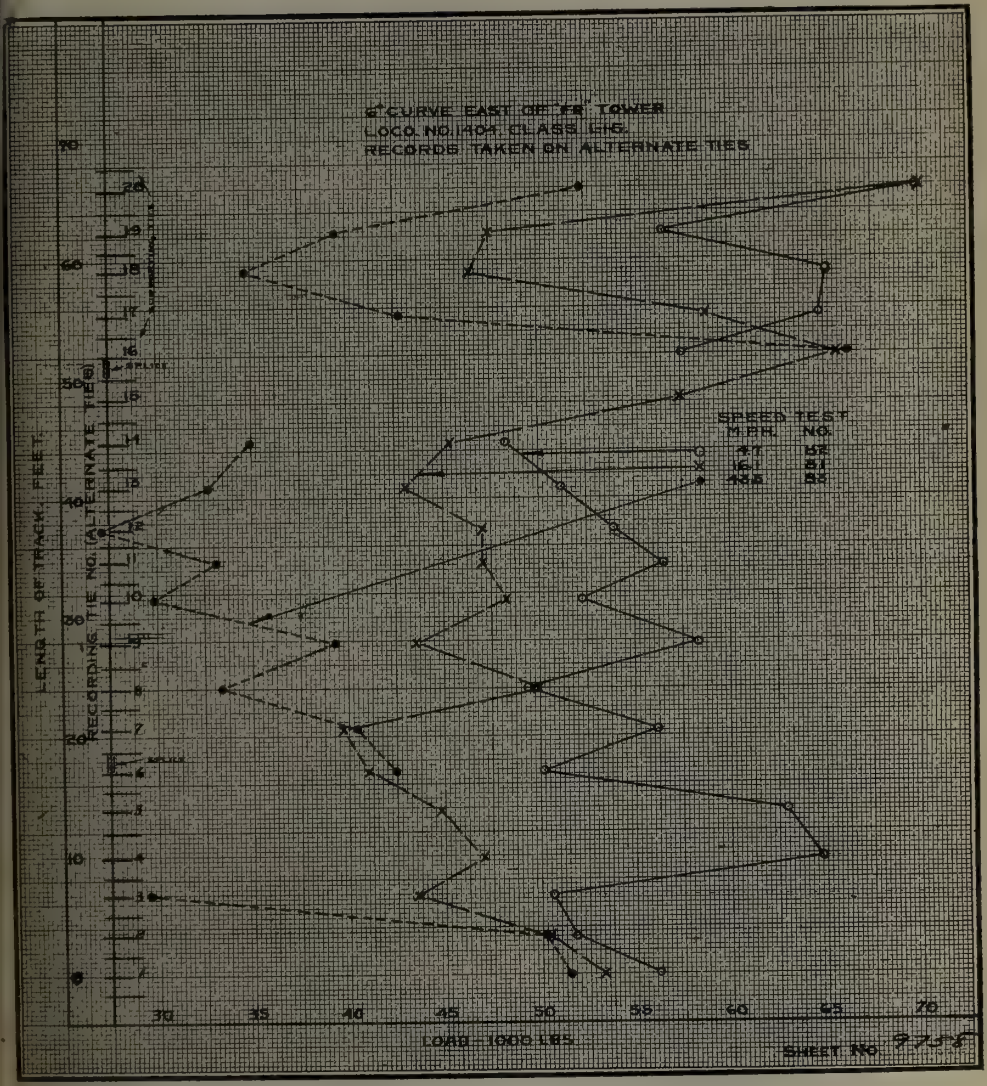
February 17, 1915.



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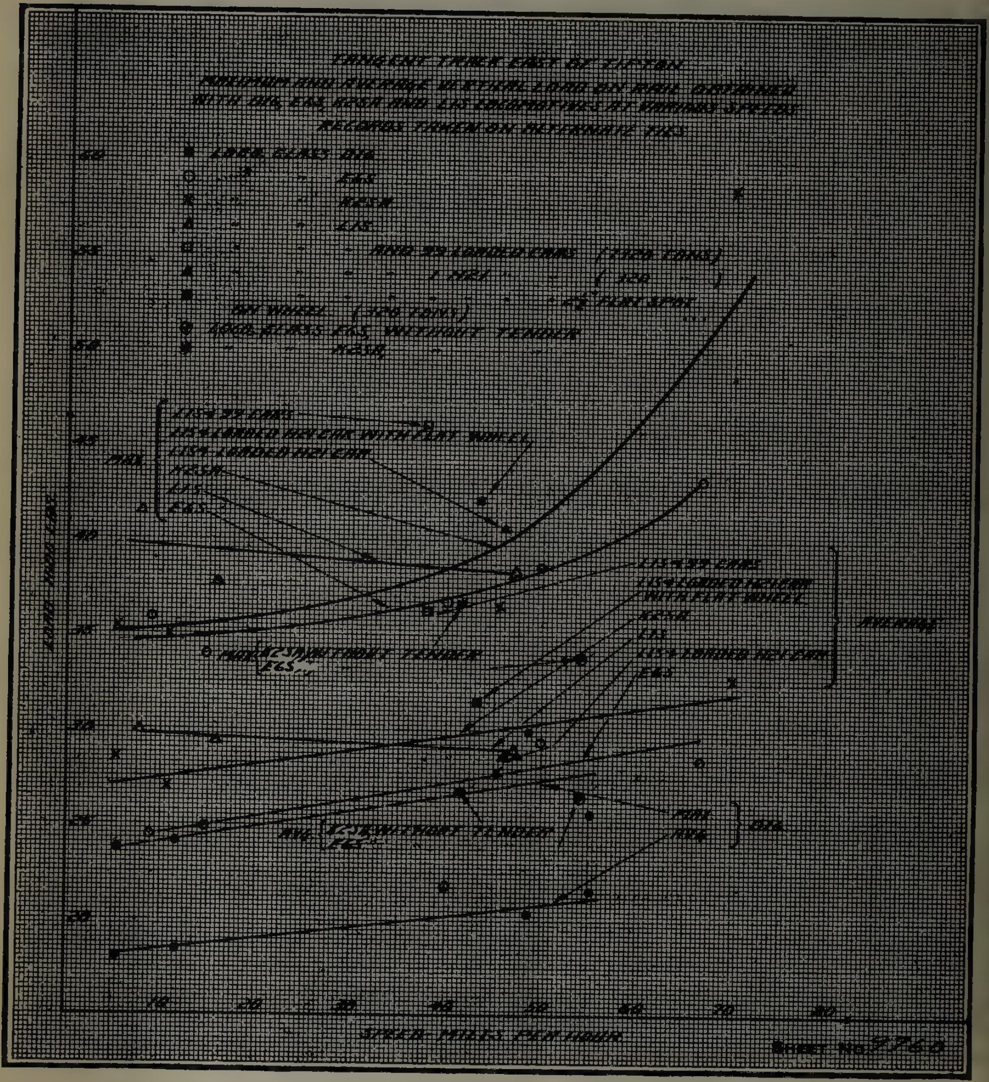

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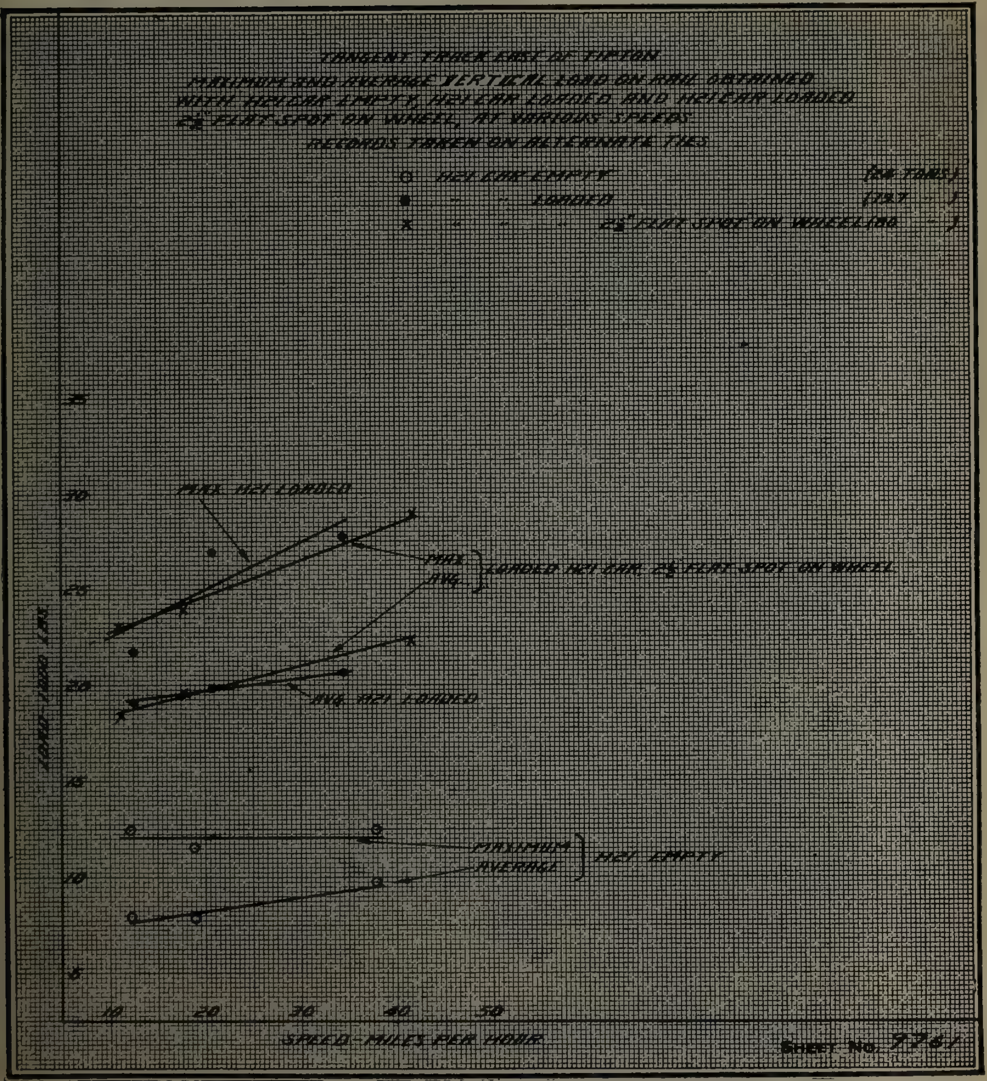

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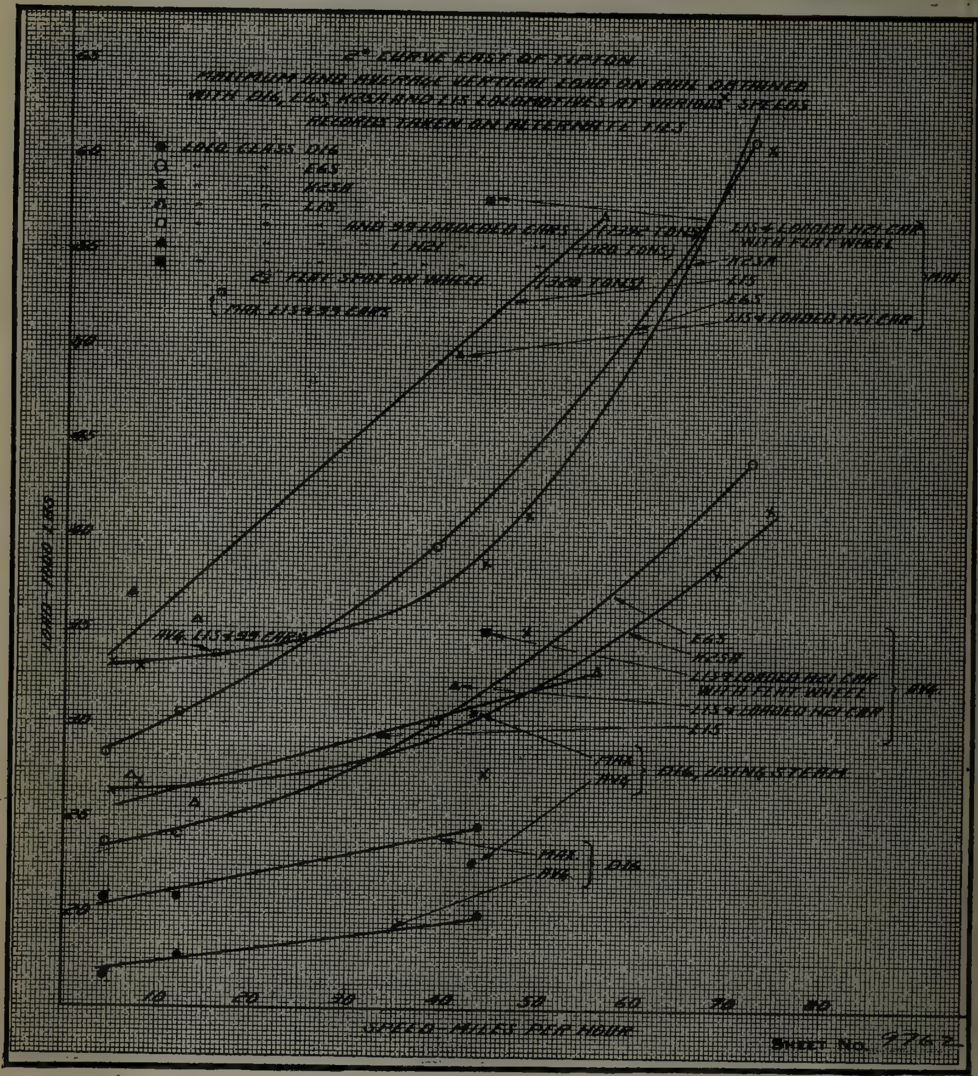
February 17, 191



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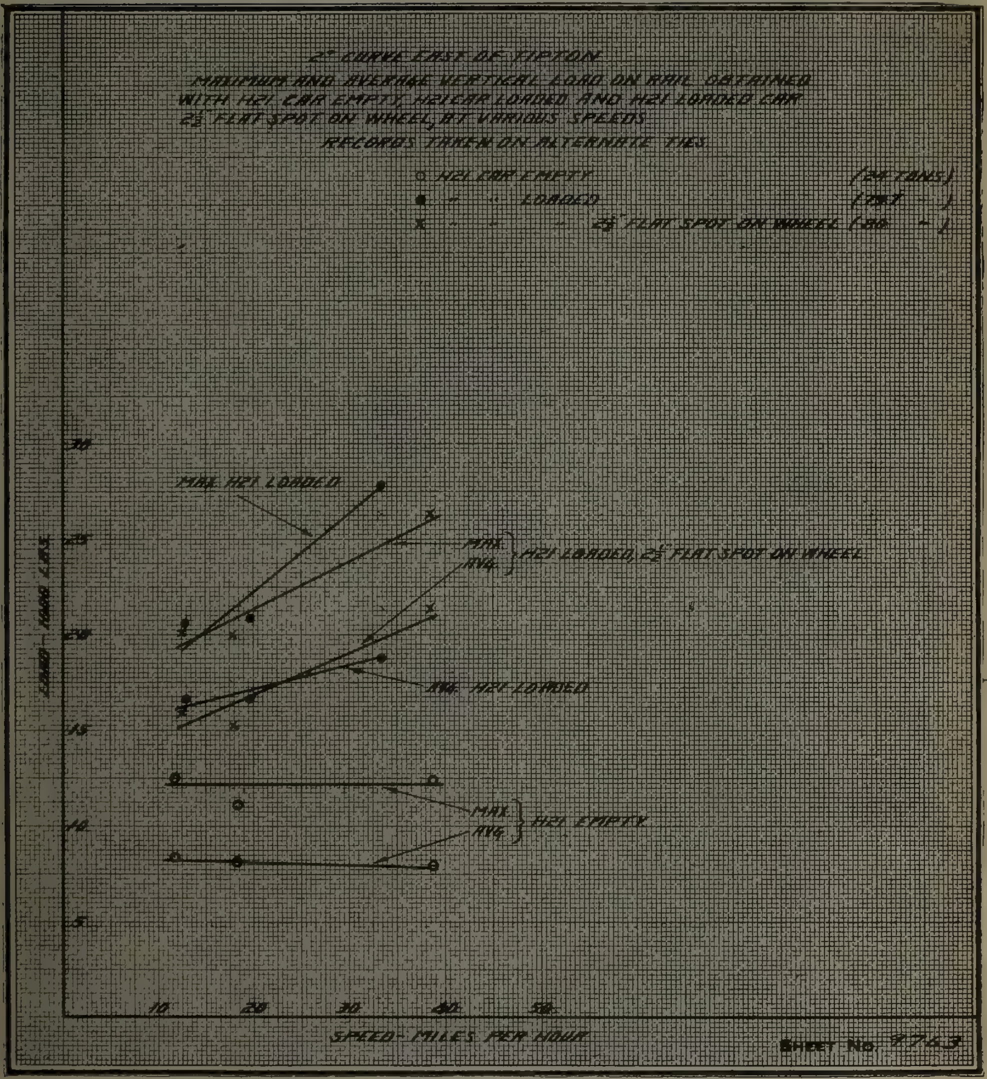

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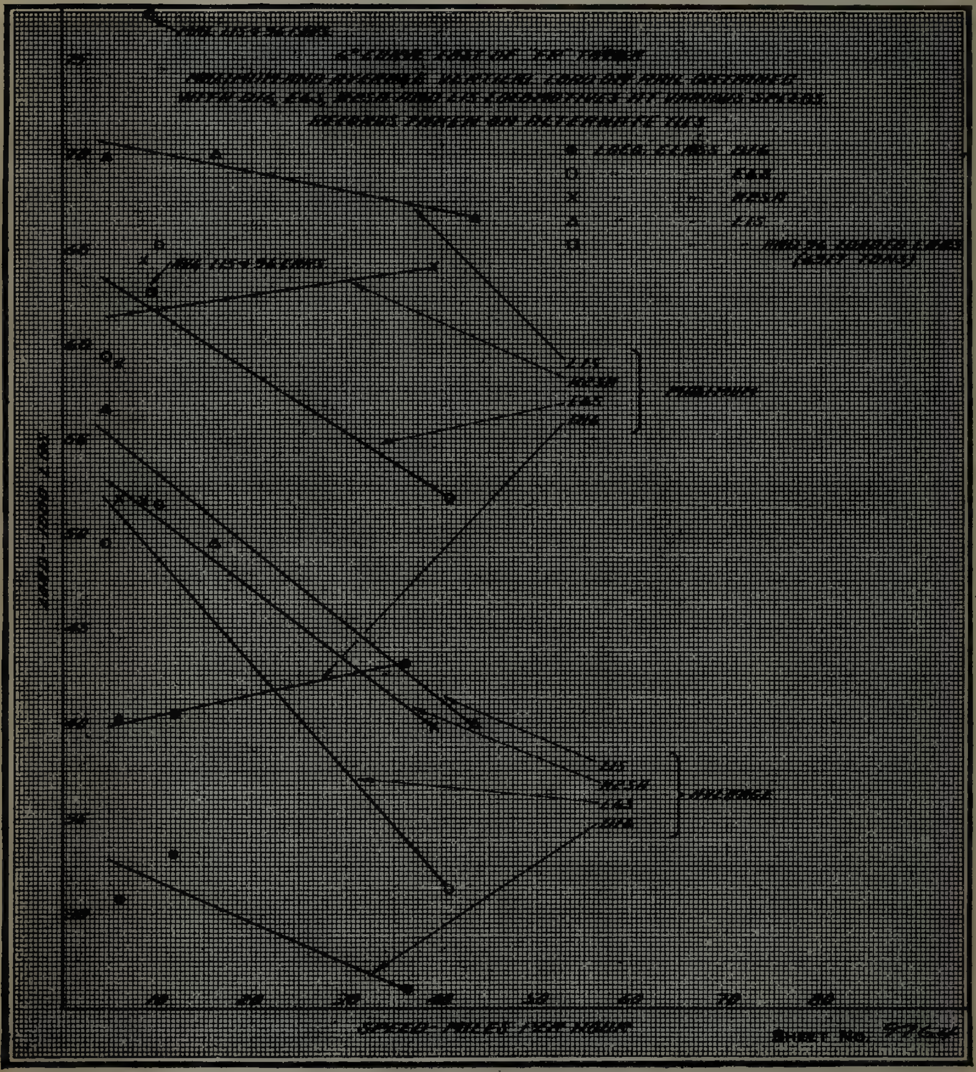
February 17, 1915.



SUMMARY OF RESULTS OF TESTS OF CLASS H-21 CAR
READINGS TAKEN ON ALTERNATE TIES.

TESTS MADE ON TANGENT TRACK							TESTS MADE ON 2 CURVE						
Test No.	Speed M.P.H.	Max. load		Min. load		Avg. Load Lbs.	Test No.	Speed M.P.H.	Max. load		Min. load		Avg. Load Lbs.
		Lbs.	Tie No.	Lbs.	Tie No.				Lbs.	Tie No.	Lbs.	Tie No.	
Empty Car													
43	12.1	12425	6	4935	4	7934	43-A	11.7	12465	1	6815	8	8397
42	18.9	11550	6	6095	3	7859	42-A	18.2	11070	3	6325	1	8107
39	37.9	12475	6	5410	4	9760	39-A	38.6	12400	3	5115	2	7920
Loaded Car													
40	12.5	21725	6	13170	4	19082	40-A	12.9	20655	4	11400	2	16584
37	20.8	26975	6	12680	3	19856	37-A	19.6	20815	9	11710	2	16558
35	34.5	27740	6	13160	4	20637	35-A	33.4	27825	3	15380	2	18789
Loaded car with flat wheel													
41	11.0	23060	6	12905	4	18446	41-A	12.5	20140	2	12150	8	15641
38	17.9	23910	6	13865	4	19586	38-A	17.9	20000	3	9700	7	15254
36	41.6	28915	6	15225	4	22338	36-A	38.5	26365	10	16410	2	21345

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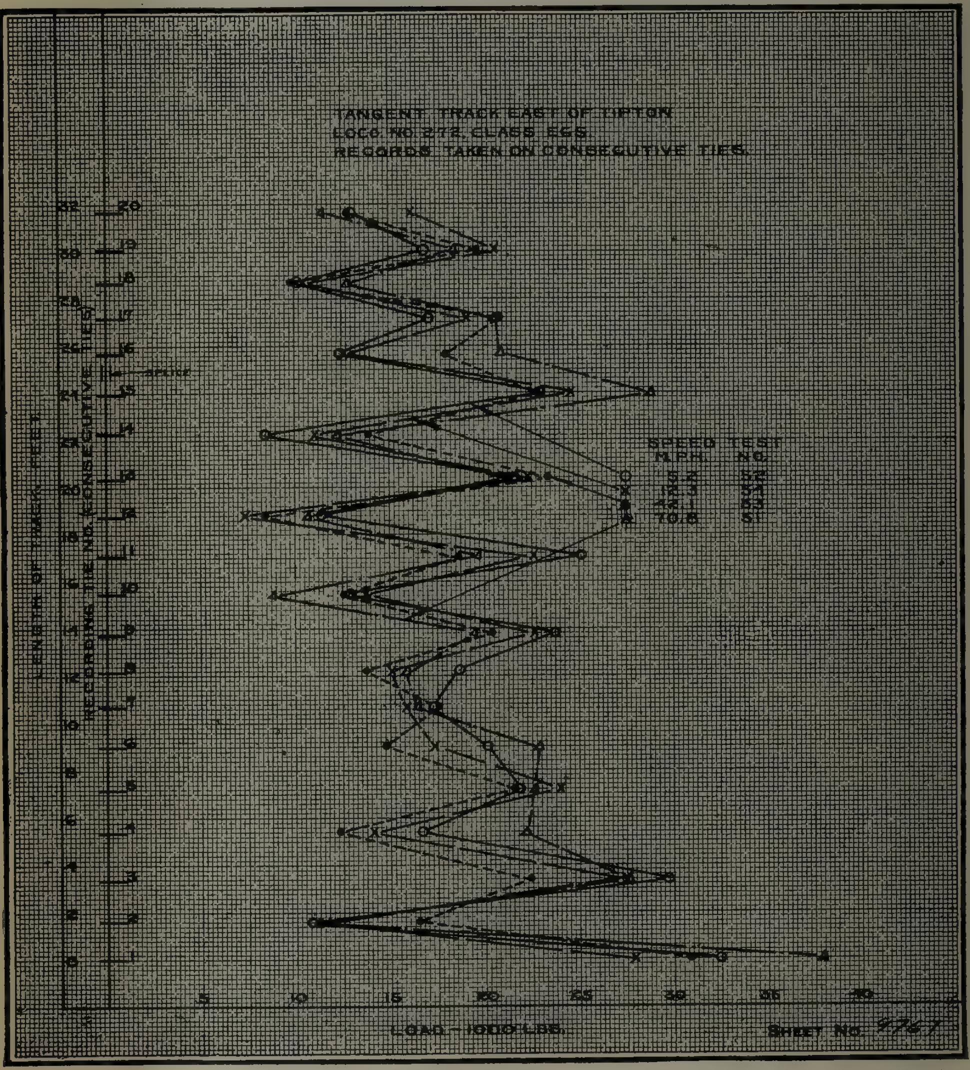
February 17, 1915.



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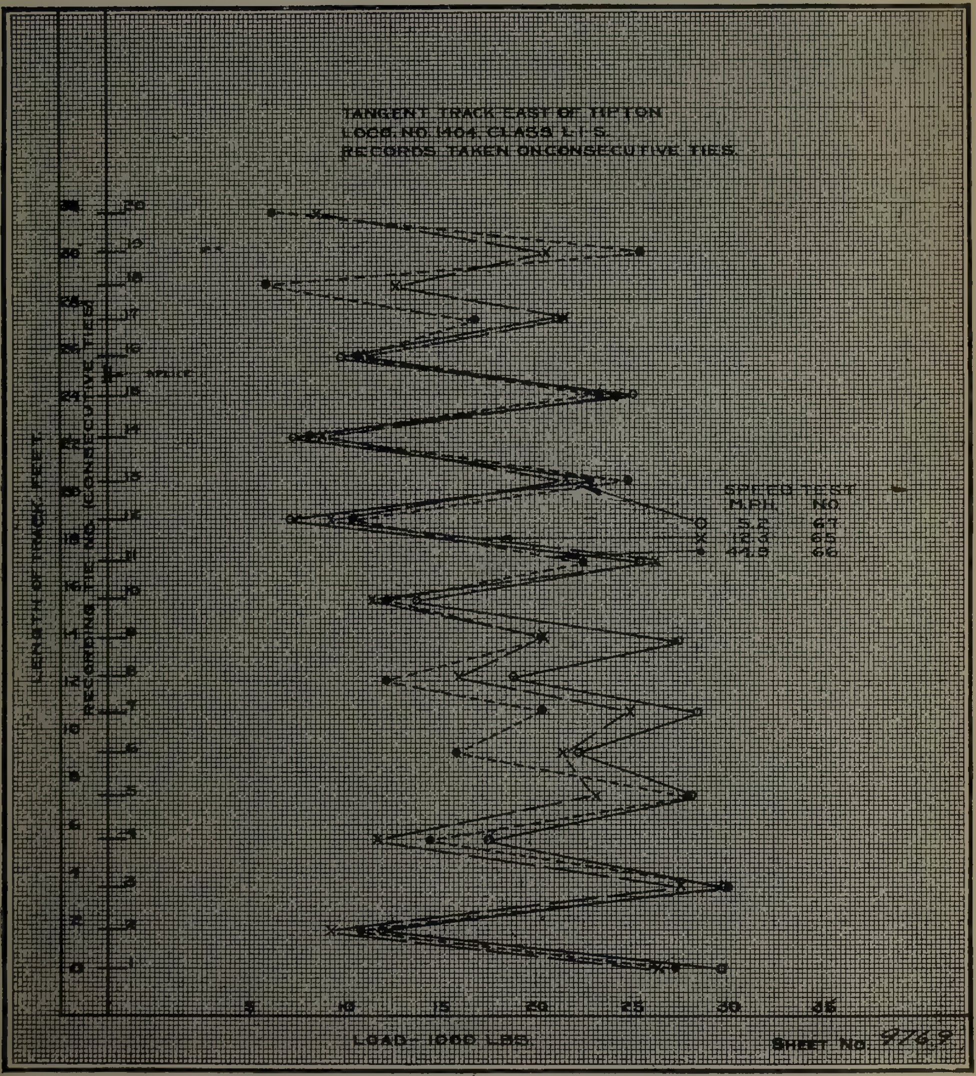

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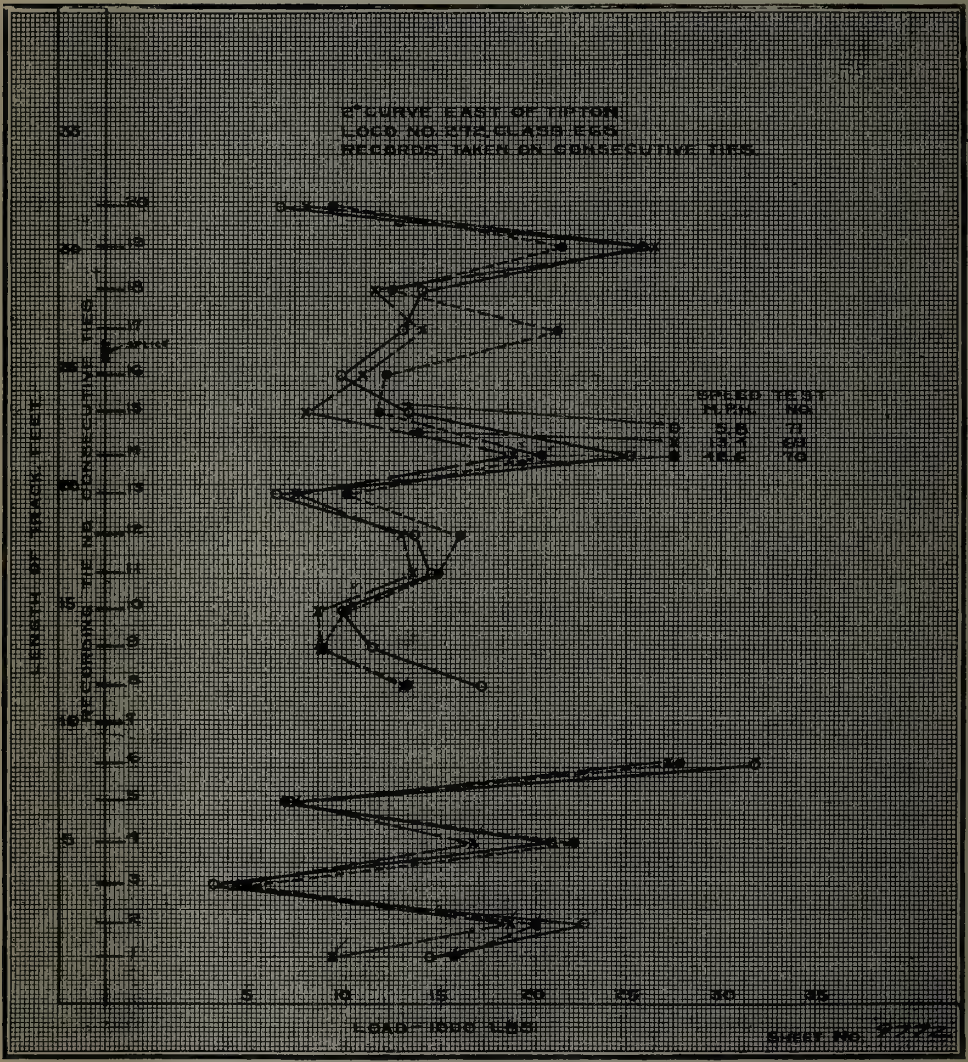

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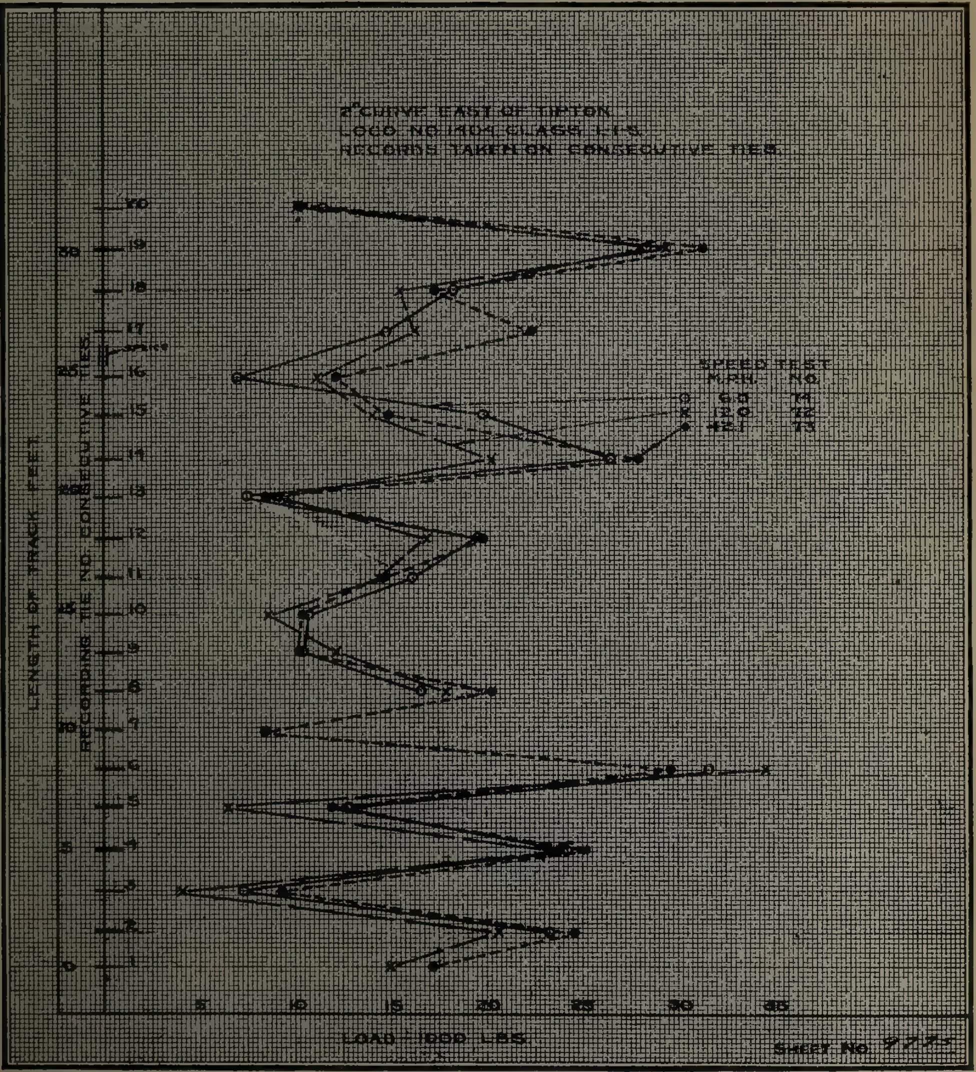

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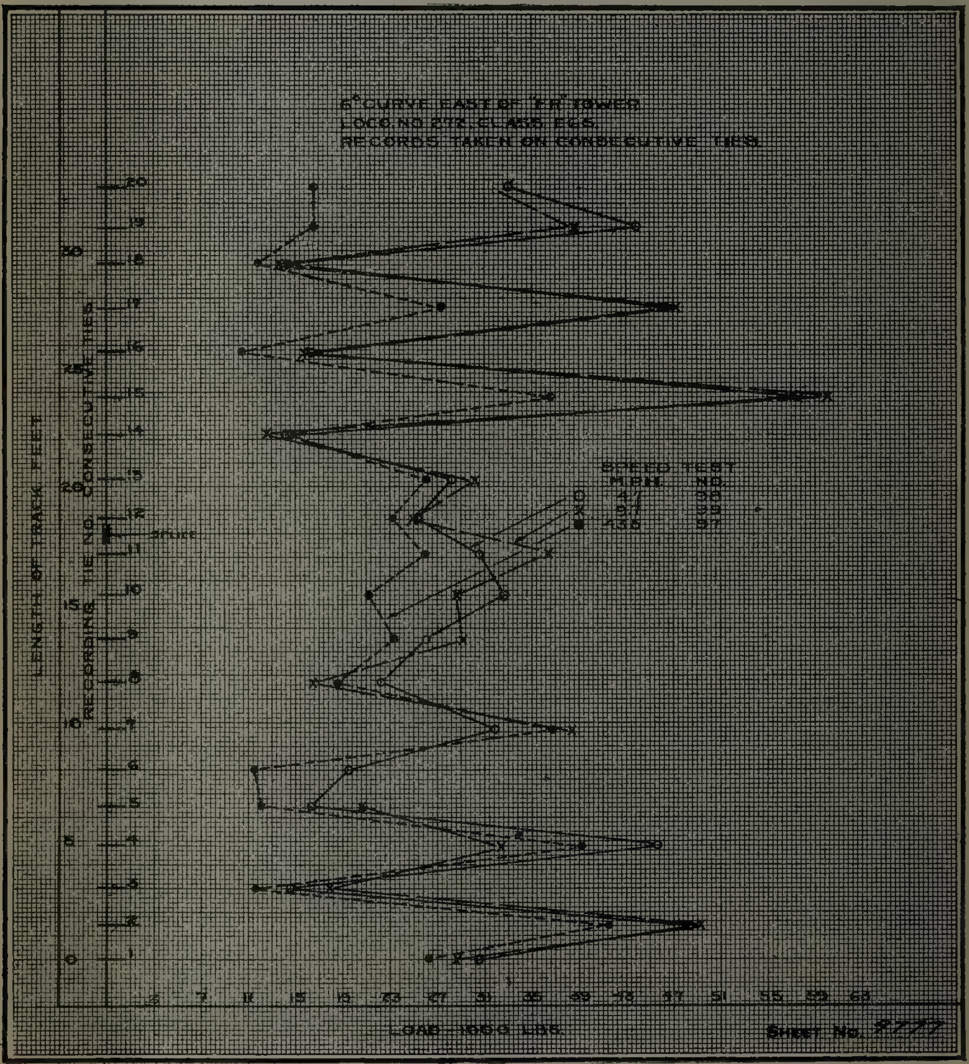

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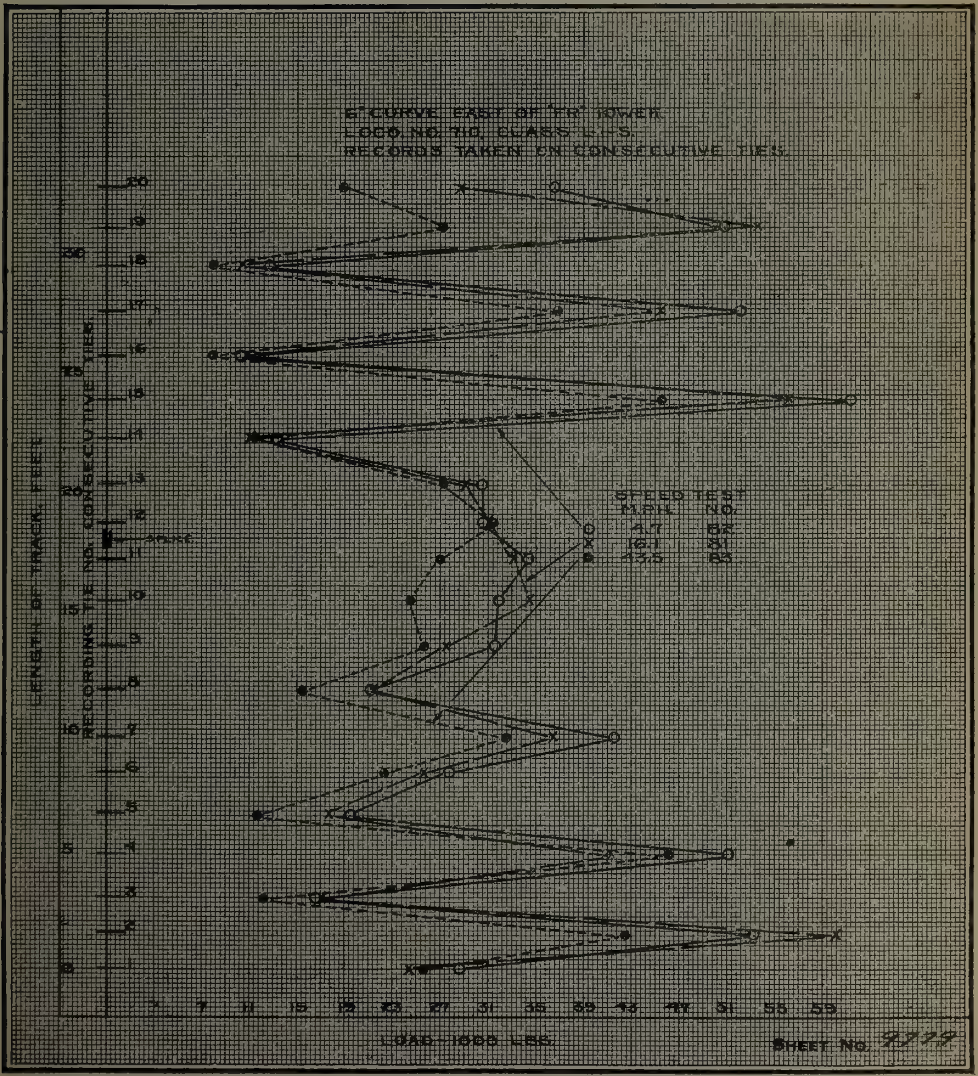

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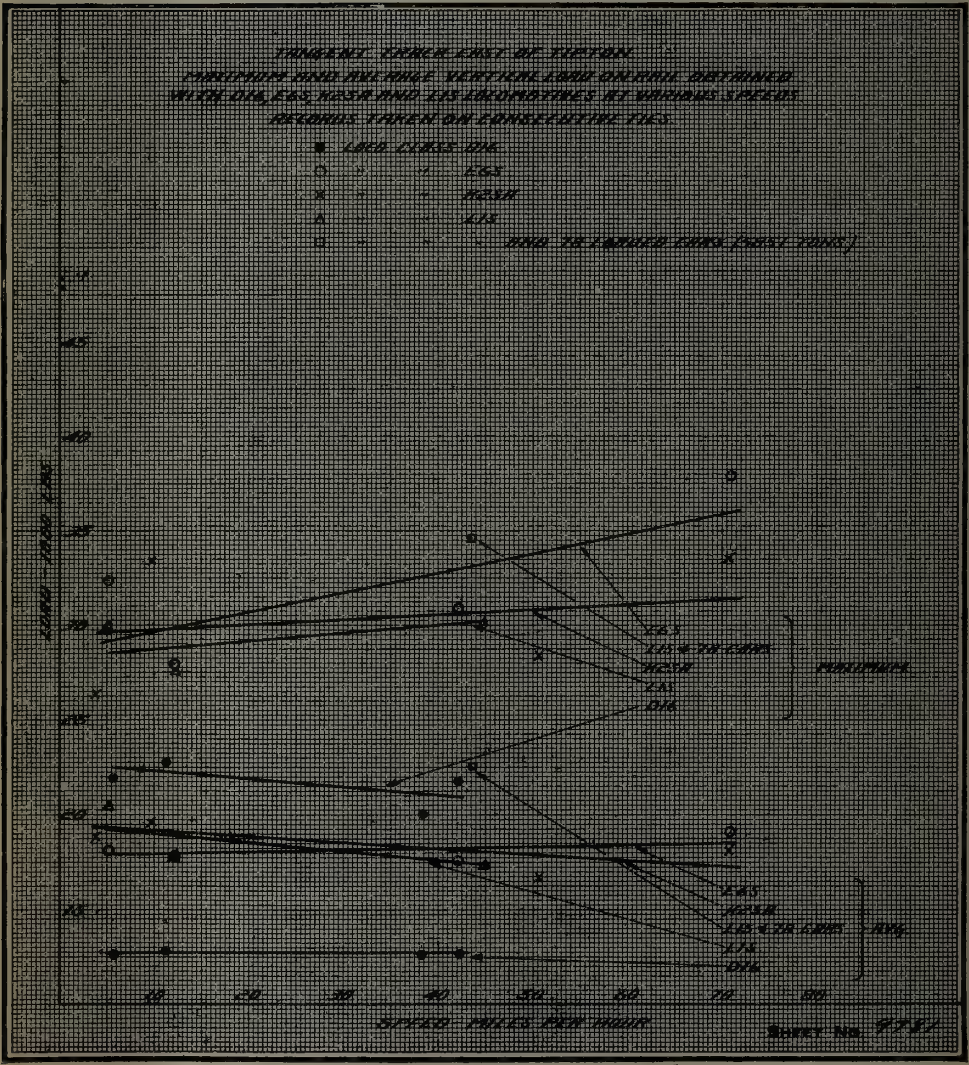

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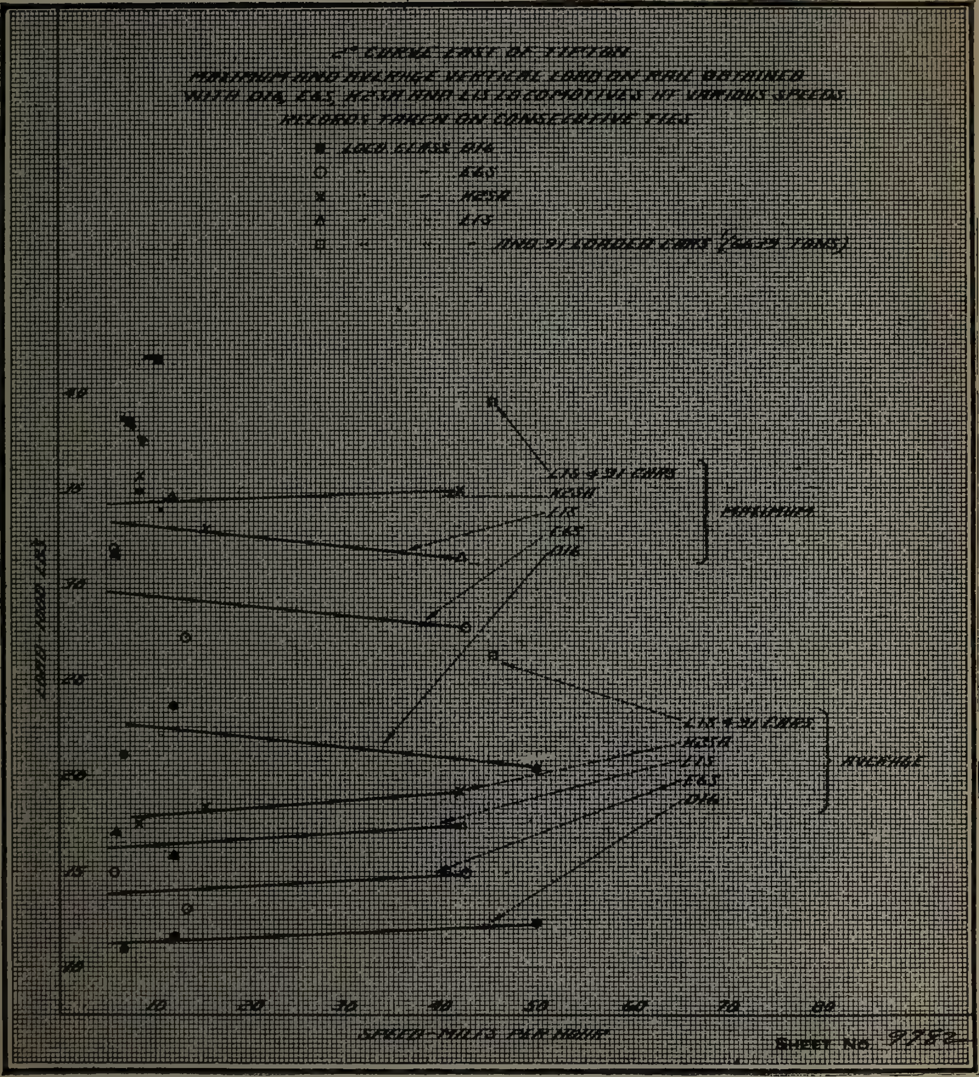
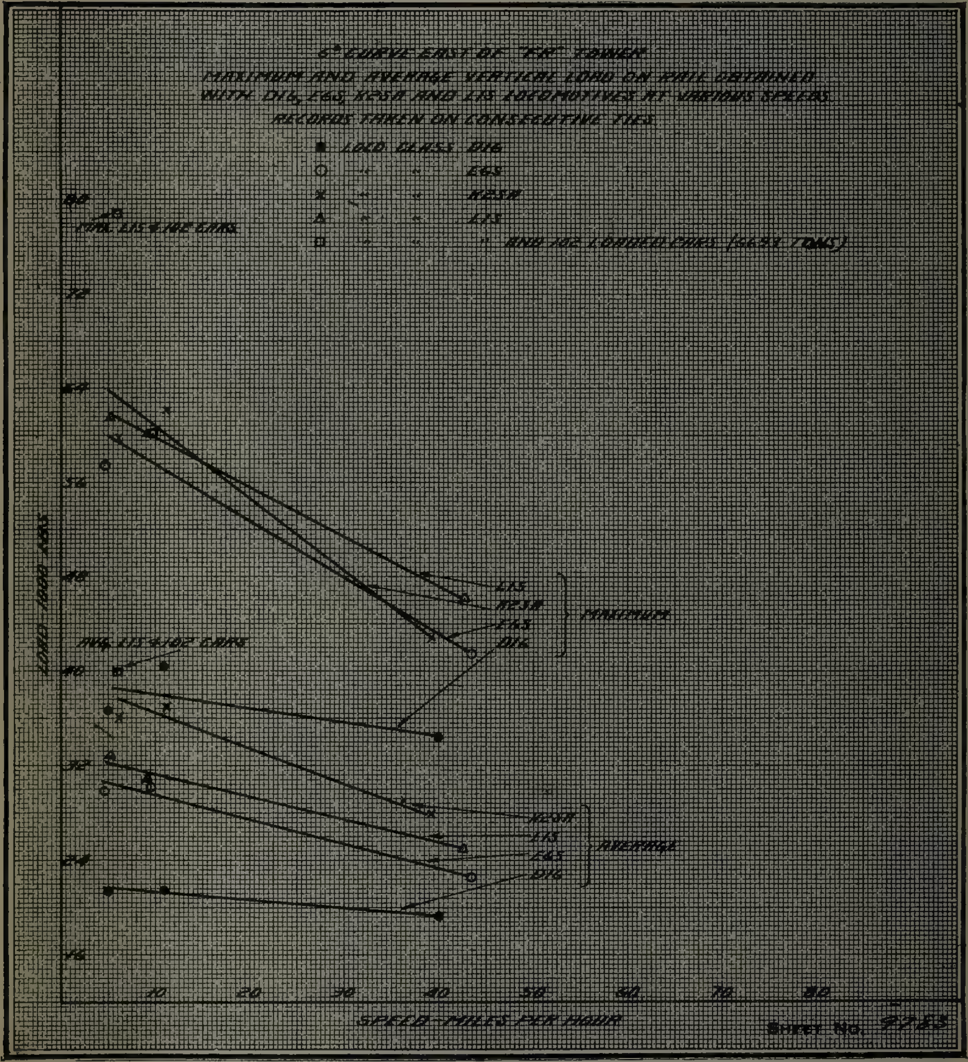
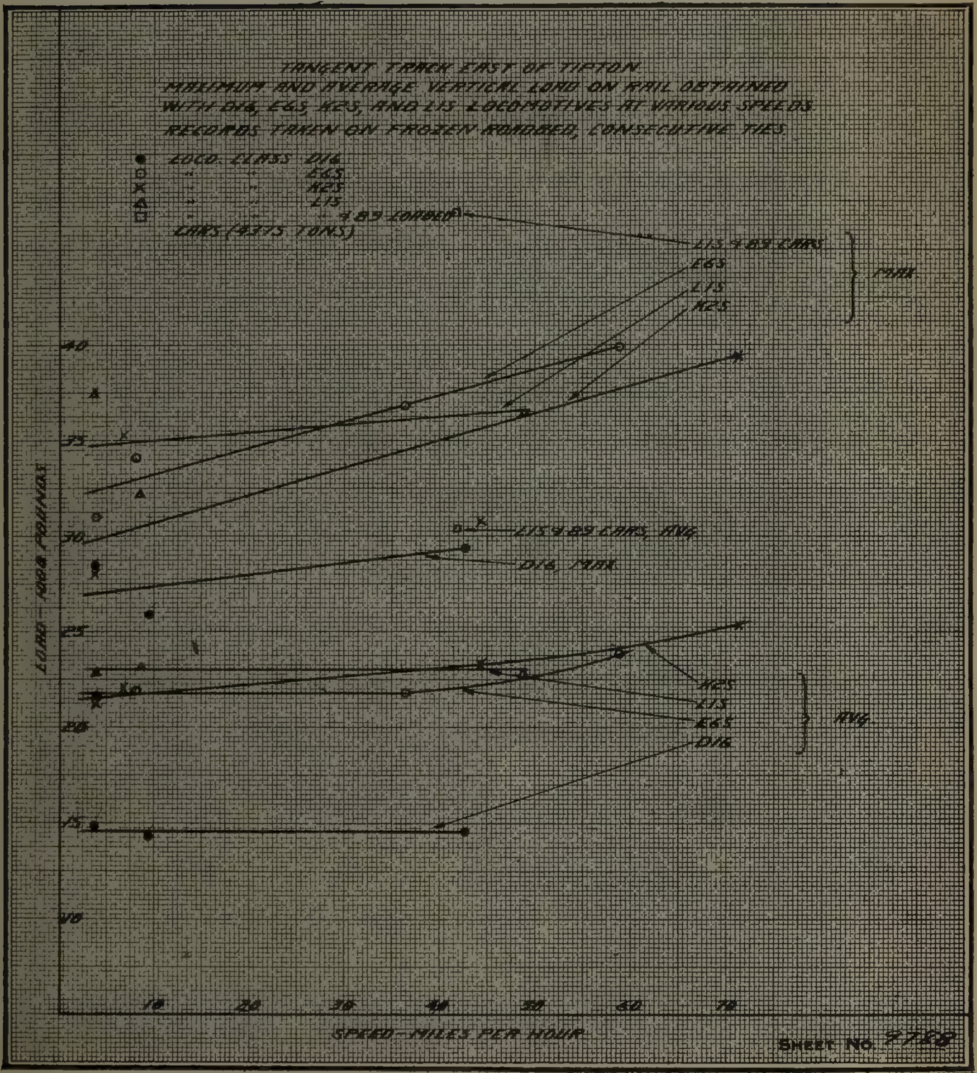


Report No. 15-12.
February 17, 1915.



Report No. 15-12.
February 17, 1915.



SUMMARY OF RESULTS OF TESTS OF CLASS D-16 LOCOMOTIVE NO. 134.

READINGS TAKEN ON ALTERNATE TIES							READINGS TAKEN ON CONSECUTIVE TIES						
		Max. load		Min. load		Avg.			Max. load		Min. load		Avg.
Test No.	Speed M.P.H.	Lbs.	Tie No.	Lbs.	Tie No.	Load Lbs.	Test No.	Speed M.P.H.	Lbs.	Tie No.	Lbs.	Tie No.	Load Lbs.
Tests made on tangent track.													
11	5.5	23750	1	12540	19	18070	63	5.7	21885	1	6110	12	12666
10	11.6	24190	18	12465	19	18372	61	11.2	22775	10	5910	12	12853
9	48.7	29920	18	14620	19	20310	60.	38.4	20050	1	3375	14	12520
12	55.1	25625	1	16500	6	21506	62	42.3	21755	1	4950	8	12646
Tests made on 2° curve.													
20	4.5	20680	18	12990	17	16652	80	6.8	21100	19	5090	3	10985
19	12.2	20810	20	13840	2	17675	78	12.2	23700	19	4650	3	11631
21	43.8	24625	10	15650	5	19991	79	50.0	20325	6	4710	7	12257
22*	43.2	30525	18	13825	2	22716							
Tests made on 6° curve.													
92	6.2	40150	20	25700	12	30840	102	5.0	36650	15	9625	14	21383
91	11.9	40310	16	28985	2	33215	101	11.0	40400	15	9500	16	21426
93	36.2	43150	16	17850	12	26042	103	40.0	34350	15	6435	18	19274
Tests on tangent track - Frozen roadbed.													
							109	3.6	28475	20	4210	12	14385
							108	9.4	25900	5	4760	12	14275
							107	42.6	29325	5	5460	12	14678

* Locomotive used steam over test track.

SUMMARY OF RESULTS OF TESTS OF CLASS E6s LOCOMOTIVE NO. 272.

Readings taken on alternate ties.							Readings taken on consecutive ties.						
		Max. Load		Min. Load		Avg. Load Lbs.			Max. Load		Min. Load		Avg. Load Lbs.
Test No.	Speed M.P.H.	Lbs.	Tie No.	Lbs.	Tie No.		Test No.	Speed M.P.H.	Lbs.	Tie No.	Lbs.	Tie No.	
TESTS MADE ON TANGENT TRACK.													
3	8.9	35950	1	12370	2	24448	52	5.2	32375	1	8490	14	18149
2	14.7	33925	20	16175	19	24846	54	12.3	27960	1	7400	12	17850
1	40.0	36725	1	12350	16	21800	53	42.1	30800	1	8480	12	17564
44	49.7	38560	3	22330	6	29349							
4	66.7	43225	1	17275	16	28437	51	70.8	37900	1	8965	10	19104
13*	54.0	33980	3	19055	15	26584							
TESTS MADE ON 2° CURVE.													
24	4.5	28310	13	14925	9	23670	71	5.8	31850	6	3240	3	14946
23	12.2	30500	13	18680	17	24115	69	13.4	27200	6	4335	3	13058
25	39.2	39400	18	25000	4	30196	70	42.6	27775	6	5030	3	14881
26	72.4	60870	19	31040	8	43845							
TESTS MADE ON 6° CURVE.													
85	4.7	59380	17	32200	3	49469	98	4.7	57520	15	14225	18	29861
84	10.2	65220	17	34500	3	51534	99	9.7	60155	15	12640	14	30204
86	40.8	51890	4	14700	13	31322	97	43.5	41515	2	10470	16	22584
TESTS MADE ON TANGENT TRACK - FROZEN ROADBED.													
							113	3.8	30965	3	11610	18	21655
							115	8.1	34075	1	12690	18	21935
							116	36.4	36775	1	10850	18	21783
							114	58.8	39875	1	10550	12	23819

* Locomotive without tender.

SUMMARY OF RESULTS OF TESTS OF CLASS K2SA LOCOMOTIVE NO. 877.

READINGS TAKEN ON ALTERNATE TIES							READINGS TAKEN ON CONSECUTIVE TIES						
		Max. load		Min. load		Avg.			Max. load		Min load		Avg.
Test No.	Speed M.P.H.	Lbs.	Tie No.	Lbs.	Tie No.	Load Lbs.	Test No.	Speed M.P.H.	Lbs.	Tie No.	Lbs.	Tie No.	Load Lbs.
Tests made on tangent track.													
7	5.3	35450	3	17505	10	28447	58	3.9	26375	11	6150	14	18814
6	10.8	34975	18	17225	17	27032	56	9.8	33400	9	10075	20	19579
5	45.4	36525	1	18620	10	27823	57	50.6	28375	1	6450	14	16768
8	70.0	58525	18	21630	15	32715	55	70.8	33610	9	5110	18	18176
14*	41.6	36660	18	18775	9	26850							
Tests made on 2° curve.													
18	5.1	33100	5	17350	9	26344	77	8.5	35625	6	6840	3	17535
17	8.1	32975	5	20150	19	26820	75	15.4	32800	19	5410	20	18319
34	44.4	38500	13	16825	8	27403	76	42.1	34850	6	7905	13	19190
16	48.7	40990	15	25880	6	34909							
15	68.9	63300	19	17960	14	38085							
33	74.1	60580	19	24955	11	41487							
Tests made on 6° curve.													
88	6.0	58940	20	42100	10	51821	106	6.1	59810	15	20975	16	36080
89	8.6	64445	4	45870	15	51740	105	11.1	62080	15	18240	16	37014
90	39.2	64055	16	30675	13	39867	104	39.2	42900	15	14200	14	27790
*Without tender.													
Tests on tangent track - Frozen roadbed.													
							117+	3.7	28100	1	11375	18	21296
							119+	6.8	35300	1	9065	12	22126
							120+	44.4	30790	5	5115	12	23259
							118+	71.4	39475	1	10650	12	25356

Locomotive No.877 used on all tests except where otherwise noted.

+ Locomotive No. 922 used in this test.

SUMMARY OF RESULTS OF TESTS OF CLASS L1S LOCOMOTIVE NO. 1404.

READINGS TAKEN ON ALTERNATE TIES							READINGS TAKEN ON CONSECUTIVE TIES						
		Max. load		Min. load		Avg.			Max. load		Min. load		Avg.
Test No.	Speed M.P.H.	Lbs.	Tie No.	Lbs.	Tie No.	Load Lbs.	Test No.	Speed M.P.H.	Lbs.	Tie No.	Lbs.	Tie No.	Load Lbs.
Tests made on tangent track.													
45	7.7	41460	13	19325	4	29998	67	5.2	30050	3	7165	12	20450
46	15.9	37750	16	19775	9	29342	65	12.3	27660	3	8535	20	17885
47	47.1	38390	20	18170	12	29027	66	44.9	30130	3	5875	18	17328
Class Lls locomotive No.1127 and 99 cars, total weight 7370 tons								Class Lls locomotive and 78 cars, Total weight 5651 tons.					
50	37.6	46050	18	28975	15	36238	59	43.5	34625	3	10150	14	22551
Class Lls locomotive and loaded class H-21 car, total weight 320 tons.													
48	46.0	40650	16	15640	13	28652							
Class Lls loco. and loaded class H-21 car with flat wheel, total wt. 320 tons.													
49	43.2	42075	18	18975	9	31563							
Tests made on 2° curve.													
30	7.2	36850	15	14825	8	27194	74	6.0	31625	6	7080	16	17058
29	14.0	35350	19	13025	9	25800	72	12.0	34600	6	4105	3	15865
28	56.3	56985	19	19730	8	32893	73	42.1	31375	19	8490	13	17362
Class Lls locomotive and 99 cars, total weight 7392 tons.								Class Lls locomotive and 91 cars, total weight 6639 tons.					
27	16.0	52720	19	22750	17	33626	64	45.4	39450	14	11240	3	26212
Class Lls locomotive and loaded class H-21 car, total weight 320 tons.													
31	41.2	49580	19	19125	8	32027							
Class Lls loco. and loaded class H-21 car with flat wheel, total wt. 320 tons.													
32	44.4	57700	19	18620	8	34815							
Tests made on 6° curve.													
82	4.7	69820	20	48275	14	56645	95+	5.2	61365	15	10240	16	32800
81	16.1	70005	20	39670	7	49506	94+	9.1	60130	2	10350	18	30780
83	43.5	66220	16	27120	12	40002	96+	42.6	46120	4	7920	16	25006
Class Lls locomotive and 96 cars, total weight 6917 tons.								Class Lls locomotive and 102 cars, total weight 6693 tons.					
87	9.2	77425	20	40750	4	62719	100+	5.9	78745	15	21200	14	39887
							+ Loco.No.710 used in these tests.						
Tests on tangent track - Frozen roadbed.													
							110	3.7	37425	1	10225	12	22829
							112	8.5	32275	7	8975	16	23163
							111	48.8	36325	4	8200	12	22875
							Class Lls loco. & 89 cars, total wt. 4615tons.						
							121	41.7	46900	1	17725	18	30440

March 10, 1915.

Mr. J. T. Wallis,
General Superintendent Motive Power,

Dear Sir:

Referring to Mr. Young's report of test to determine the load imposed on each tie in track, which accompanied your favor of February 24th, we note that in the test on alternate ties "the intermediate ties were not tamped solid, and in this way practically the entire load on one rail was supported on the recording ties."

From the diagrams it seems evident that this condition (ties alternately solid and loose) prevailed throughout the tests on consecutive ties, as high readings are shown on alternate ties and low readings on the intervening ties. This is characteristic of all the diagrams to a marked degree, but is especially clear on sheet No. 9770 showing result of test with loaded train, probably because, with the long train, the inequalities due to equipment are lost and those due to track conditions brought out prominently.

If the above conclusion is correct it would seem that the average of the readings in the test on consecutive ties would more nearly approximate the maximum load sustained by each tie in normal track than the maximum readings would.

In view of the doubt thus raised as to this one element in this otherwise very thorough and satisfactory test do you not think it would be well to have as many of the tests repeated as are necessary to assure ourselves that the results obtained truly represent normal track conditions, preparing the track by tamping the ties as uniformly as possible and leaving it in service at least a month before making the test?

Yours truly,

(Signed) W. G. Coughlin,
Engineer Maintenance of Way.

March 18, 1915.

Mr. J. T. Wallis,
General Superintendent Motive Power.

Dear Sir:

Noting your favor of March 15th relative to tests to determine the load imposed on each tie in track, we would like to have further tests, as enumerated below, made to determine the amount of the influence of irregular tamping on the results of previous tests.

In making these supplementary tests the track should be prepared by lowering twenty consecutive ties, tamping them as uniformly as possible. The track should be kept in service and the ties tamped every day for at least ten days before the test is made.

The supplementary tests we desire are as follows; all to be made with an E6s locomotive:

2 tests at 6 to 8 m. p. h. on tangent.
6 tests at 70 m. p. h. on tangent.
2 tests at 6 to 8 m. p. h. on low side 6-degree curve.
6 tests at 40 m. p. h. on high side 6-degree curve.

Yours truly,

(Signed) W. G. Coughlin,
Engineer Maintenance of Way.

May 14, 1915.

Members Committee on Screw-Spike Test,

Gentlemen:

Enclosed please find copy of report from Mr. J. T. Wallis dated May 6, 1915, on supplementary tests to determine the load sustained by tie-plates in track.

We have added to the diagrams full black lines indicating the average load imposed on each tie in the several tests and a dotted black line showing the average load on all the ties.

As all the tests were made with the same locomotive and the speeds were very uniform, it would seem entirely proper to average the runs.

This test shows very much better results than the previous one, the loads on the several ties being within a much narrower range except at two points in the high speed test, viz., ties Nos. 4 and 16. As these ties are about 20 ft. apart the excess load is doubtless due to lack of balance in the reciprocating parts of the locomotive.

As none of the tie-plates (except at the points mentioned) carried more than 26,000 lbs. (averaging the six runs), the locomotive having the heaviest wheel load in present use and running at the highest permissible speed, it would seem extravagant to use a higher factor than this in designing a tie-plate for use in tangent track.

It will be necessary for us to have the results of the tests on curved track (which you will note Mr. Wallis states will be made as soon as track is in proper shape) before we can proceed to the determination of the proper area for our proposed tie-plates.

Referring to the tests of crushing strength of new and old cross-ties decided upon at our last meeting, would advise that we have arranged for such tests so far as the old ties are concerned, but in the case of the new ties we have concluded that the results of the United States Government tests of a very large number of samples would be more reliable than any we could get from the comparatively small number of tests we would be able to make. We enclose for your information statement of Government tests referred to.

Yours truly,
(Signed) W. G. Coughlin,
Chairman, Committee on Screw-Spike Test.

Altoona, Pa., May 6, 1915.

Mr. W. G. Coughlin,
Engineer Maintenance of Way,

Dear Sir:

Referring to your letters of March 10th and 18th, in reference to Mr. C. D. Young's report No. 15-12, dated February 24, 1915, on load sustained by tie-plates:

In accordance with your request we have made the supplementary tests on tangent track, the track having been inspected by the Screw-Spike Committee and by Mr. J. C. Crawford, Assistant Engineer, and found to be in satisfactory condition for these trials. The tests on the 6-degree curve track which you requested made in your letter of March 18th will be carried out as soon as the track, which is being raised about 18 inches, is in proper condition for the trials.

These supplementary tests were made to ascertain if, in the previous tests made on consecutive ties, the high readings shown on alternate ties and low readings on the intervening ties were not due to track conditions which indicated that the ties were alternately solid and loose, and if this condition existed whether the average readings thus obtained would not more nearly approximate the maximum load sustained by each tie in normal track than the maximum readings obtained with the track in the condition above indicated.

The tests were made on the tangent track with locomotive 272, Class "E6s", which is the same locomotive as was used in the previous tests.

The results of the low speed tests are shown on sheet No. 10007, and for the high speed tests on sheet No. 10008. These sheets are comparable with the results shown on sheet No. 9769 in the original report, and you will note that they show the same irregularity in the load which is sustained by individual ties as was shown in the previous tests, although not to such a marked degree. So far as the results on tangent track are concerned we feel that these supplementary tests have practically duplicated the former tests in the character of the readings observed on the consecutive ties and in the maximum and average load figures. The following table shows the maximum, minimum and average loads obtained in the low and high speed tests made in November, 1914, and given in report No. 15-12 and the supplementary tests made in April, 1915:

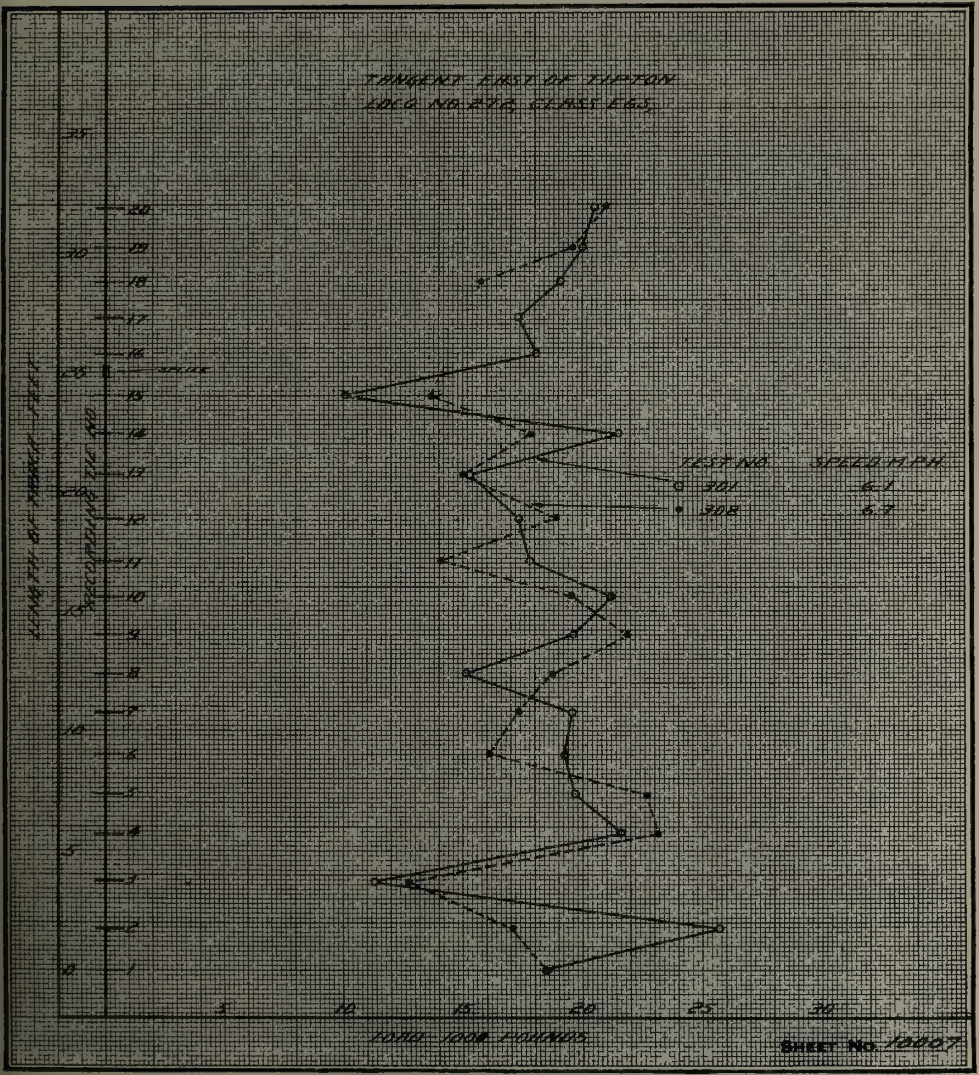
	Maximum Load, Lbs.		*Minimum Load, Lbs.*		*Average Load, Lbs.*	
Tests Made	*Nov.,* 1914.	*April,* 1915.	*Nov.,* 1914.	*April,* 1915.	*Nov.,* 1914.	*April,* 1915.
Speed 5 to 6 M. P. H......	32,375	25,695	8,490	10,125	18,149	18,200
Speed 65 to 70 M. P. H.......	37,900	35,075	8,965	13,825	19,104	22,900

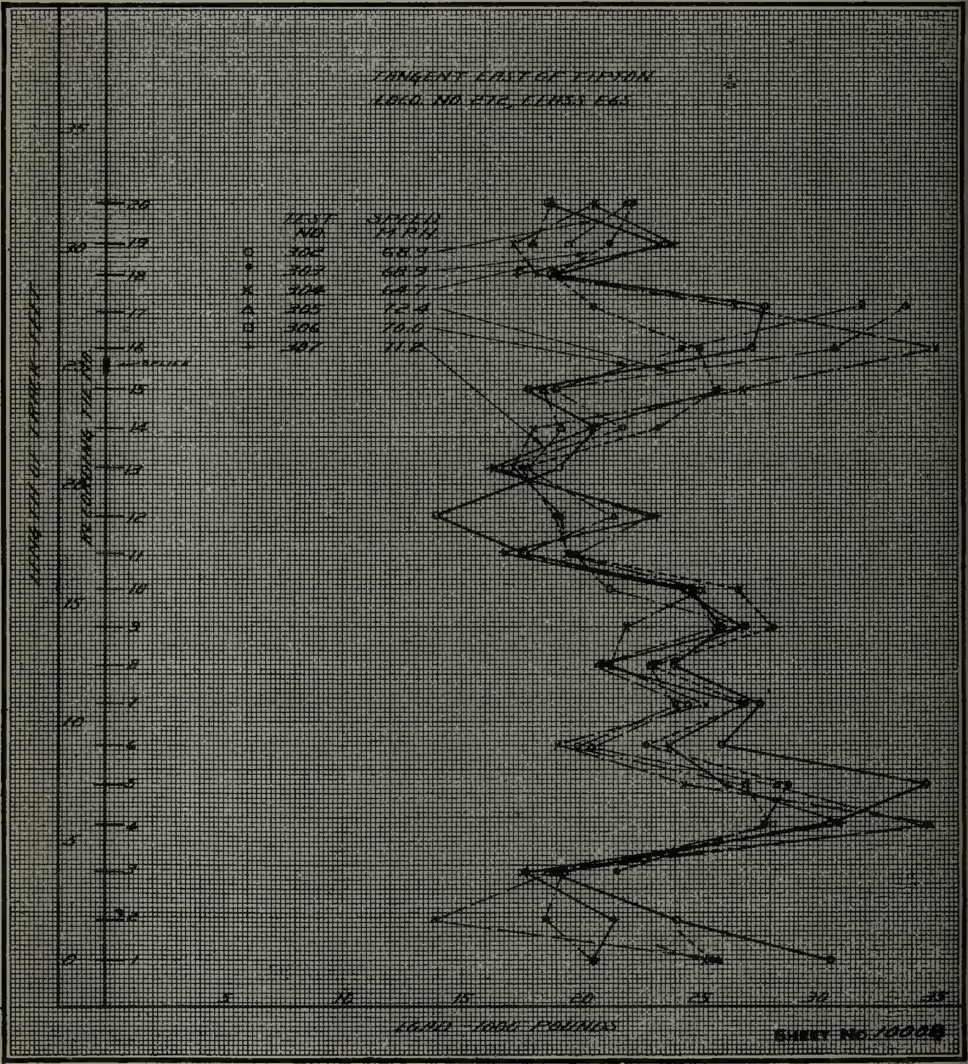
From this table you will note that the low speed tests made in April, 1915, give a higher minimum and a lower maximum load than in the tests made in November, 1914. The average figures are approximately the same for the two series of tests. At the high speeds the tests made in April, 1915, show a higher minimum and average load and a lower maximum load than in the tests previously made.

The results of these supplementary tests do not indicate that the average loads found in the previous tests (in which there were indications that the ties were alternately solid and loose) approximate the maximum load sustained by each tie under the track conditions obtaining in these supplementary tests.

Although the maximum load obtained at high speeds was about 8 per cent. less than the probable compromised figure of 38,000 lbs., mentioned in paragraph 34 of report No. 15-12, for tie-plate loads on tangent track, we feel that in general these supplementary tests confirm the conclusions drawn from the previous tests.

Yours truly,
(Signed) J. T. Wallis,
General Superintendent Motive Power.


TANGENT EAST OF TIPTON
LOC'G NO. 272, CLASS E6S
LENGTH OF TRACK FEET
RECORDING TIE NO.
SPLICE
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
5
10
15
20
25
30
LOAD 1000 POUNDS
TEST NO.
SPEED M.P.H.
○ 301
6.1
● 308
6.7
SHEET No. 10007


TANGENT EAST OF TIPTON
LOCO. NO. 272, CLASS E6S
TEST NO.
SPEED M.P.H.
○ 302 68.9
● 303 68.9
× 304 69.7
△ 305 72.4
⊡ 306 70.0
+ 307 71.2
LENGTH OF TRACK, FEET
RECORDING TIE NO.
SPIKE
35
30
25
20
15
10
5
0
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
5
10
15
20
25
30
35
LOAD—1000 POUNDS
SHEET No. 10008

CRUSHING STRENGTH OF CROSS-TIES.

	Fiber Stress at Elastic Limit.	
White Oak	850	pounds per square inch
Walnut	500	" " " "
Black Locust	1,400	" " " "
Cherry	450	" " " "
Chestnut	400	" " " "
Sassafrass	500	" " " "
Mulberry	400	" " " "
Red Oak	775	" " " "
Honey Locust	1,500	" " " "
Hickory	1,000	" " " "
Beech	600	" " " "
Hard Maple	700	" " " "
Hackberry	500	" " " "
Sycamore	425	" " " "
Red Gum	450	" " " "
Ash	400	" " " "
Soft Maple	500	" " " "
Black Gum	500	" " " "
Butternut	275	" " " "
Birch	450	" " " "
Elm	450	" " " "
Longleaf Pine	500	" " " "
Cypress	500	" " " "
Shortleaf Pine	400	" " " "

June 2, 1915.

Mr. W. G. Coughlin,
Engineer Maintenance of Way,

Dear Sir:

Further in connection with your letter of March 18th, and our letter of May 6th, relative to supplementary tests to determine load imposed on each tie in track:

We have carried out the tests on the high and low side of the 6-degree curve with locomotive No. 272, class E6s, which is the same locomotive as was used in the previous tests on the low side of this cure.

The track on which records were obtained had been placed in condition for installing the apparatus for a period of three weeks previous to the tests, and we were advised by Mr. J. C. Crawford, Assistant Engineer, that the track was in satisfactory condition before the tests were made.

The results of the tests on the low side of the curve are shown on sheet No. 10053. The results on this sheet are comparable with the results of the low speed tests given on sheet No. 9777.

The results of the tests made on the high rail of the curve are shown on sheet No. 10054. The speed at which the tests were made varied between 25 and 45 miles per hour; but from the loads found at the various speeds a curve has been plotted which is shown on sheet No. 10055, from which it is possible to obtain with reasonable accuracy the probable average and maximum load for a speed of 40 miles per hour, which was the nominal speed of the tests.

The following table shows the maximum, minimum and average loads obtained in the tests made on this curve in November, 1914, and given in report No. 15-12, and the supplementary tests made in May, 1915. For comparison we have shown the results found on the tangent track given in report No. 15-12, as well as the supplementary tests made in April, 1915, which were given in my letter of May 6, 1915.

TESTS MADE ON LOW RAIL OF 6-DEGREE CURVE.

Tests Made	*Maximum Load, Lbs.* *Nov.,* 1914.	*May,* 1915.	*Minimum Load, Lbs.* *Nov.,* 1914.	*May,* 1915.	*Average Load, Lbs.* *Nov.,* 1914.	*May,* 1915.
Speed 4 to 5 M. P. H.	57,520	44,875	14,225	13,060	29,861	32,050

TESTS MADE ON HIGH RAIL OF 6-DEGREE CURVE.

Speed 40 M. P. H.	.....	29,000	.....	*4275	....N	18,000

*Obtained in tests made at 34.1 M. P. H.

TESTS MADE ON TANGENT TRACK.

Tests Made	*Nov.,* 1914.	*April,* 1915.	*Nov.,* 1914.	*April,* 1915.	*Nov.,* 1914.	*April,* 1915.
Speed 5 to 6 M. P. H.	32,375	25,695	8,490	10,125	18,149	18,200
Speed 65 to 70 M. P. H.	37,900	35,075	8,965	13,825	19,104	22,900

From this table you will note that on the low side of the curve the supplementary tests made in May, 1915, show a lower maximum and a higher average load than was found in the previous tests.

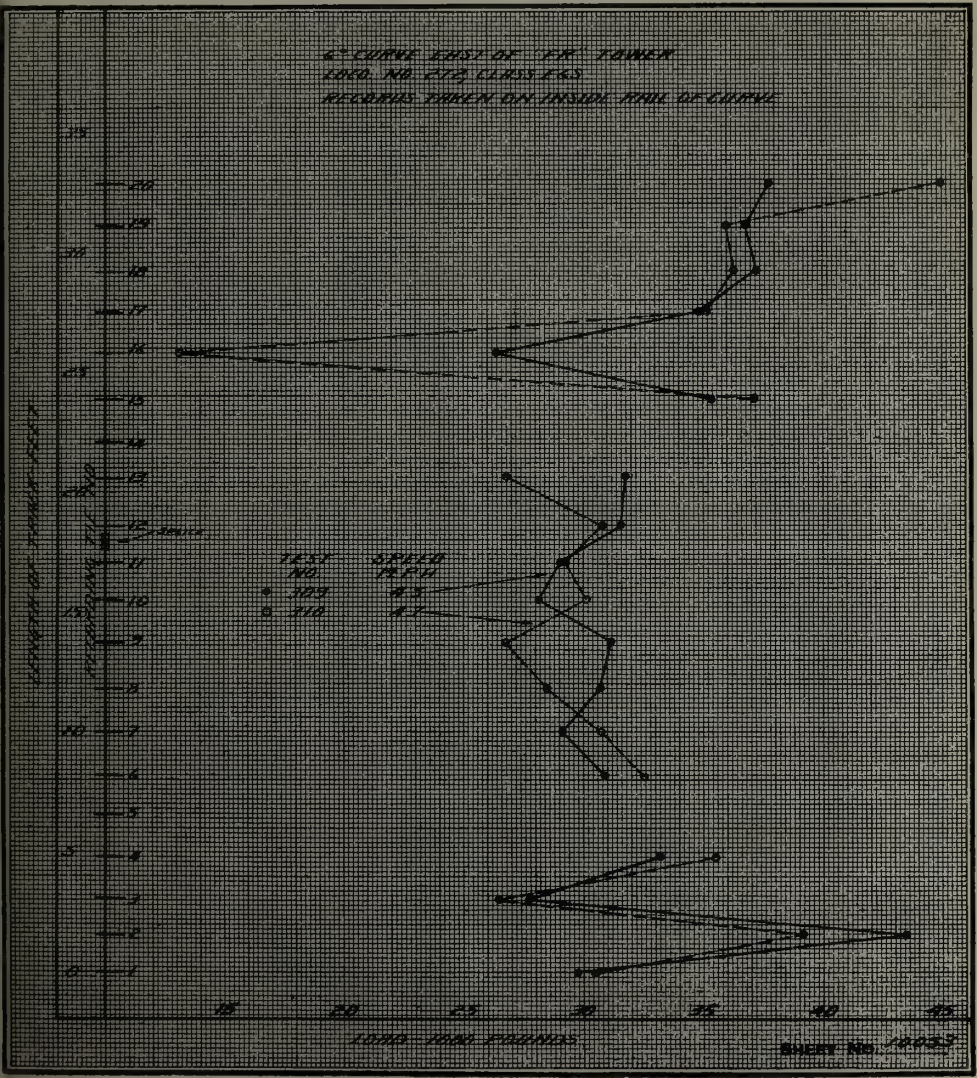
Referring to the results of the supplementary tests made in April and May, 1915, it will be observed that the maximum load on the low rail of the 6-degree curve is 27 per cent. greater than that shown for the high speed on tangent track.

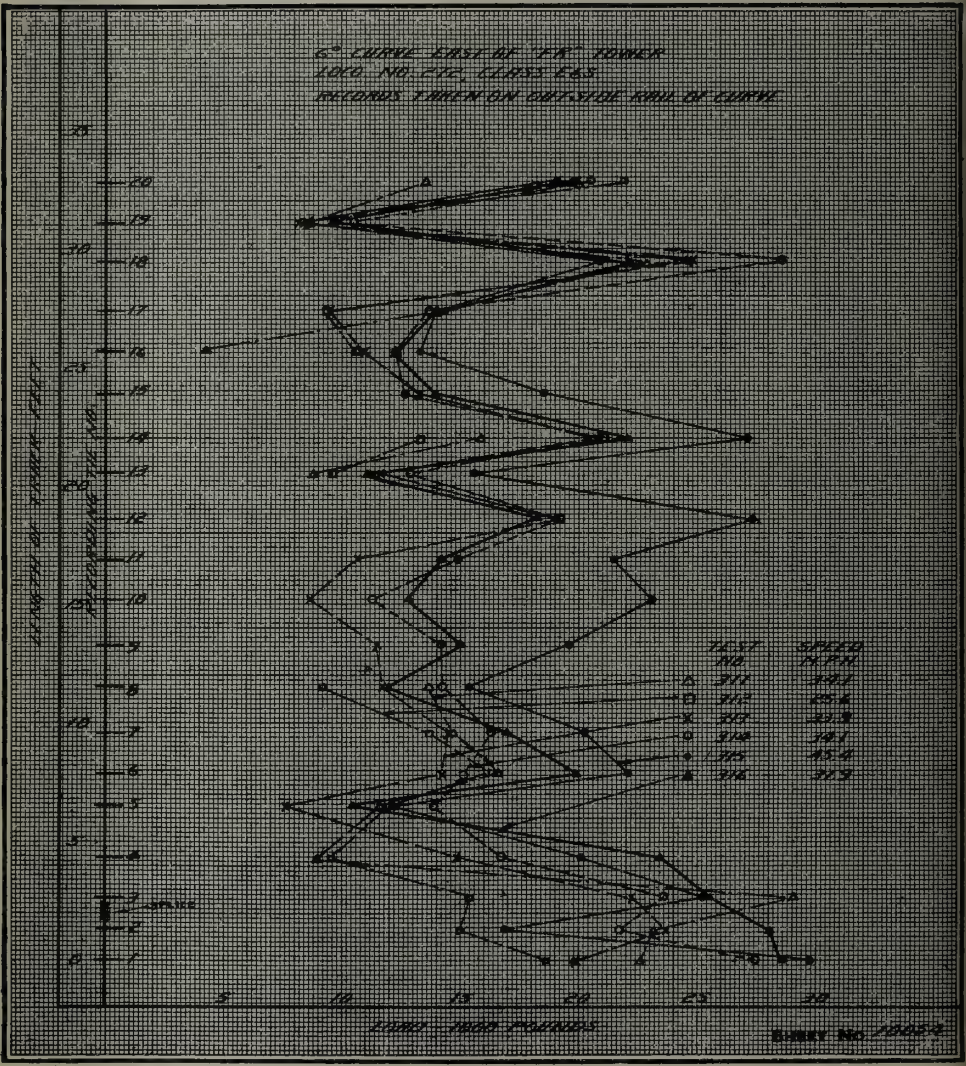
Based on the tests made in November, 1914, the maximum load for the 6-degree curve is 52 per cent. greater than was found for the tangent track.

This variation in maximum load for the 6-degree curve of from 27 to 52 per cent. over that found for tangent track is probably due to the improved track condition on the 6-degree curve at the time the last series of tests was made. These percentages applied to the suggested figure for the plate load on tangent track of 38,000 lbs., given in the report of the Engineer of Tests, dated February 24, 1915, and which was not materially changed by the results of the supplementary tests sent you under date of May 6, 1915, give a probable range for the maximum load on the curve from 48,000 lbs. to 58,000 lbs., depending on the track condition obtaining.

Summarized, the first and second series of tests indicate that if the tie-plates are to be designed for the maximum load for tangent track, that it should be based upon a load between 35,000 and 38,000 lbs.; and where the plates are to be used on curves, where the conditions are comparable with this 6-degree curve, that there should be an increase in the area over that for the tangent track of from 27 to 52 per cent., the former figure having been obtained by these supplementary tests and the latter by the previous tests. The 52 per cent. increase figure seems to be supported by a comparison between the average figures obtained on curve and tangent track in the November and May series of tests, and therefore it would seem to be the preferable one to use when designing tie-plates for the sharp curve conditions.

Yours truly,
(Signed) J. T. Wallis,
General Superintendent Motive Power.


6° CURVE EAST OF "F.R." TOWER
LOCO. NO. 272, CLASS E6S
RECORDS TAKEN ON INSIDE RAIL OF CURVE
TEST NO.
SPEED M.P.H.
● 309 8.5
○ 310 4.7
LENGTH OF TRACK FEET
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
15
20
25
30
35
40
45
LOAD 1000 POUNDS
SHEET NO. 10053


6° CURVE EAST OF "FR" TOWER
LOCO. NO. 272, CLASS E6S
RECORDS TAKEN ON OUTSIDE RAIL OF CURVE
LENGTH OF TRACK-FEET
RECORDING TIE NO.
35
30
25
20
15
10
5
0
20
19
18
17
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6
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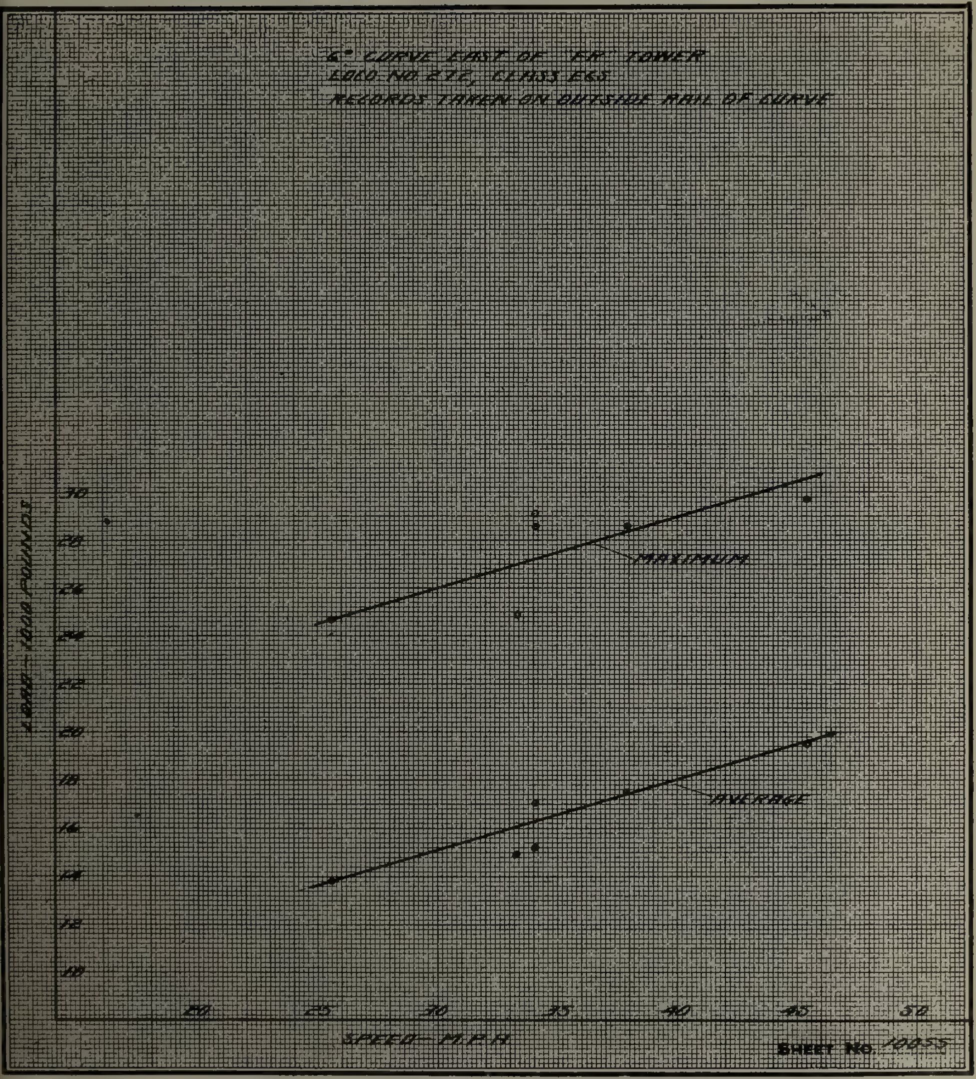
4
3
2
1
SPIKE
TEST NO.
SPEED M.P.H.
△ 311 34.1
□ 312 25.4
X 313 23.
○ 314 34.1
● 315 45.4
▲ 316 37.9
5
10
15
20
25
30
LOAD—1000 POUNDS
SHEET No. 10052


6° CURVE EAST OF "FR" TOWER
LOCO. NO. 27E, CLASS E6S
RECORDS TAKEN ON OUTSIDE RAIL OF CURVE
MAXIMUM
AVERAGE
LOAD—1000 POUNDS
30
28
26
24
22
20
18
16
14
12
10
20
25
30
35
40
45
50
SPEED—M.P.H.
SHEET No. 10055

DISTRIBUTION OF LOAD OVER TIES.

TEST DEPARTMENT.

Altoona, Pa., April 16, 1915.

Mr. J. T. Wallis,
General Superintendent Motive Power.

As requested by Mr. W. G. Coughlin, Engineer Maintenance of Way, in his letters to you of October 10, 1914, and February 17, 1915, tests have been made to determine the distribution of load over ties effected by 100-lb. rail.

METHOD OF CONDUCTING TESTS.

2. The tests were made on stone ballast roadbed about 400 feet west of Hollidaysburg Station on the Petersburg Branch.

3. The recording apparatus used is described in our report No. 15-12. Records were taken under both rails for 10 consecutive ties spaced 20 inches from center to center.

4. The track on which the tests were made was prepared two weeks previous to the tests and was used in service and kept in excellent condition during this time.

5. The load was applied to the rails by means of two twenty-ton hydraulic jacks which rested on a suitable base rounded to the same contour as an 80-inch wheel. The method of transmitting the load on the jacks to the rail is shown on sheet No. 9924.

6. The load placed on the rail was determined by means of a steel plate containing four 1-inch steel balls on which rested an impression plate, these being placed between the jacks and the beam shown on sheet No. 9924.

7. The distribution of load over ties was determined for three kinds of rails, i. e., P. R. R. section 100-lb. rail well worn, P. S. section 100-lb. new rail, and P. R. R. section 125-lb. new rail. A sectional view of the worn rail is shown on sheet No. 9886.

8. The loads were applied at two points on each of the rails as follows: Directly over tie No. 5, and between ties Nos. 5 and 6.

RESULTS.

9. On sheets Nos. 9887 to 9890, inclusive, is shown graphically the load supported on each tie when the load was applied to the rail, for the worn and new 100-lb. rails. It will be observed on these sheets that the outline of curves obtained when the load was applied over a tie, correspond with those obtained when the load was applied between two of the ties, and further that the load diminishes as the distance from the point where the load was applied increases.

10. On sheets Nos. 9891 and 9892 is shown the results obtained with new 125-lb. rail. A comparison of these two sheets shows that the distribution of load over the ties remains practically the same whether the load is placed over a tie or between two ties, and also that the loads recorded on the recording ties farthest from the point at which the load was applied were greater than those obtained at a similar point with 100-lb. rail.

11. A study of sheets Nos. 9887 to 9892, inclusive, shows that the load supported on each tie changed to some extent with each succeeding test. We believe this was due to the shifting of the ballast under the ties because it was found necessary to tamp the ties most directly affected by the load several times, and once it was necessary to tamp tie No. 10 to bring the ties to the proper alinement.

12. On sheet No. 9926; p. 215, is shown the relation between the concentrated load applied to the rail and the sum of the loads found on all the recording devices for the corresponding test.

CONCLUSIONS.

13. The following table shows the loads applied to the rail, and the maximum load recorded on one tie, and the ratio of the maximum load to the load on the rail:

Load Applied Over a Tie.			*Load Applied Between Ties.*		
	Max. Load on Tie.			*Max. Load on Tie.*	
Load on rail Pounds.	*Pounds.*	*Per cent. of load on rail.*	*Load on rail Pounds.*	*Pounds.*	*Per cent. of load on rail.*
WORN RAIL 100 LBS. PER YARD.					
35,345	15,475	44	36,735	18,745	51
39,240	16,745	43	49,920	17,950	36
56,730	25,870	45	73,575	30,085	41
NEW RAIL 100 LBS. PER YARD.					
45,480	22,400	49	54,465	25,875	48
58,395	21,515	37	54,820	19,400	35
67,625	28,820	43	55,585	21,085	38
NEW RAIL 125 LBS. PER YARD.					
28,240	15,875	56	29,840	16,245	54
46,915	13,995	30	45,590	17,750	39
75,575	19,910	26	68,295	17,325	25

14. An analysis of the results in the above table indicates the following:

(a)—The results obtained with the worn and the new 100-lb. rail indicate that the wearing away of the rail does not materially affect the distribution of load over the ties.

(b)—The ratio of maximum load on a tie to the load on the rail is not materially changed by transferring the load from directly over the tie to midway between two ties.

(c)—The maximum load on a tie is about 45 per cent. of the load on the rail when 100-lb. rail is used.

(d)—With 125-lb. rail the ratio of the maximum load on a tie to the load on the rail decreases as the load on the rail increases. Briefly stated, the maximum load on a tie with 125-lb. rail was found to be about 35 per cent. of the load on the rail when this load is 50,000 lbs. and 25 per cent. of the rail load when 75,000 lbs. is applied. The loads given above are within the axle loads on the locomotives used on our lines.

15. Since observing the performance of the ties under this test, we hardly feel that this is a proper method of making an investigation of this kind, as the question of the roadbed yielding under the heavy concentrated load was apparent. Such yielding, therefore, would tend to cause erratic pressure to be shown on the different ties which, if the ties had been placed on a fixed foundation, results might have been otherwise. This is particularly exemplified in the wide variation between the total load found on the ties as compared with the concentrated load which was applied to them, as in some tests the increase in total load on all of the ties was 1.6 times the concentrated load, whereas in one test it amounted to as much as 4.1 times the concentrated load, although in this

latter case the concentrated load is relatively low. This higher total and variation is probably due to the yielding of the track structure and resulted in lever action which occurred between the ties.

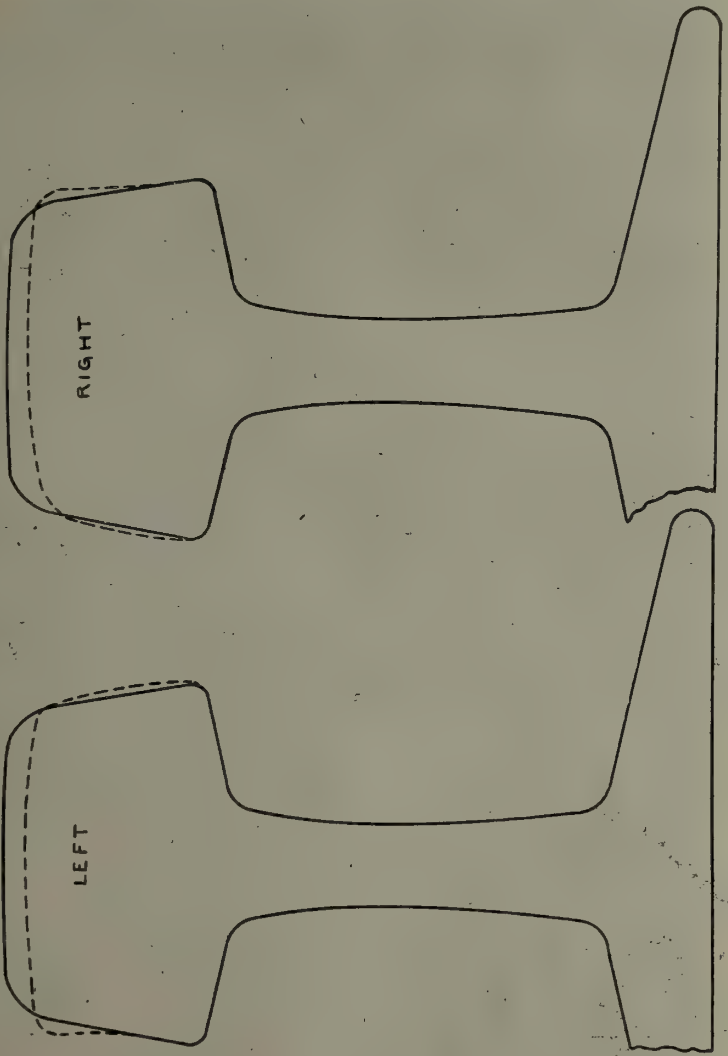
16. Another objection to the test is that the load was applied by jacks and not by a moving concentrated load. This in turn might have a slight effect upon the results.

17. We believe, therefore, that this test only expresses indications and that no definite conclusions can be drawn from the results.

18. Probably a better way to obtain the distribution of concentrated load when the rail is considered as a beam would be to lay ties of uniform thickness on a permanent foundation such as one of the tracks in our Erecting Shops, and then lower a load upon the rail. This test, however, has the objection that when the rail is so placed it does not have the continuous beam effect which is found in the track and, therefore, there may be a tendency of concentration of load upon the ties directly beneath the load which probably does not occur with the track in service.

19. It would appear, if the indications are all that Mr. Coughlin desires as to the question of load distribution, these tests give him sufficient data for this purpose.

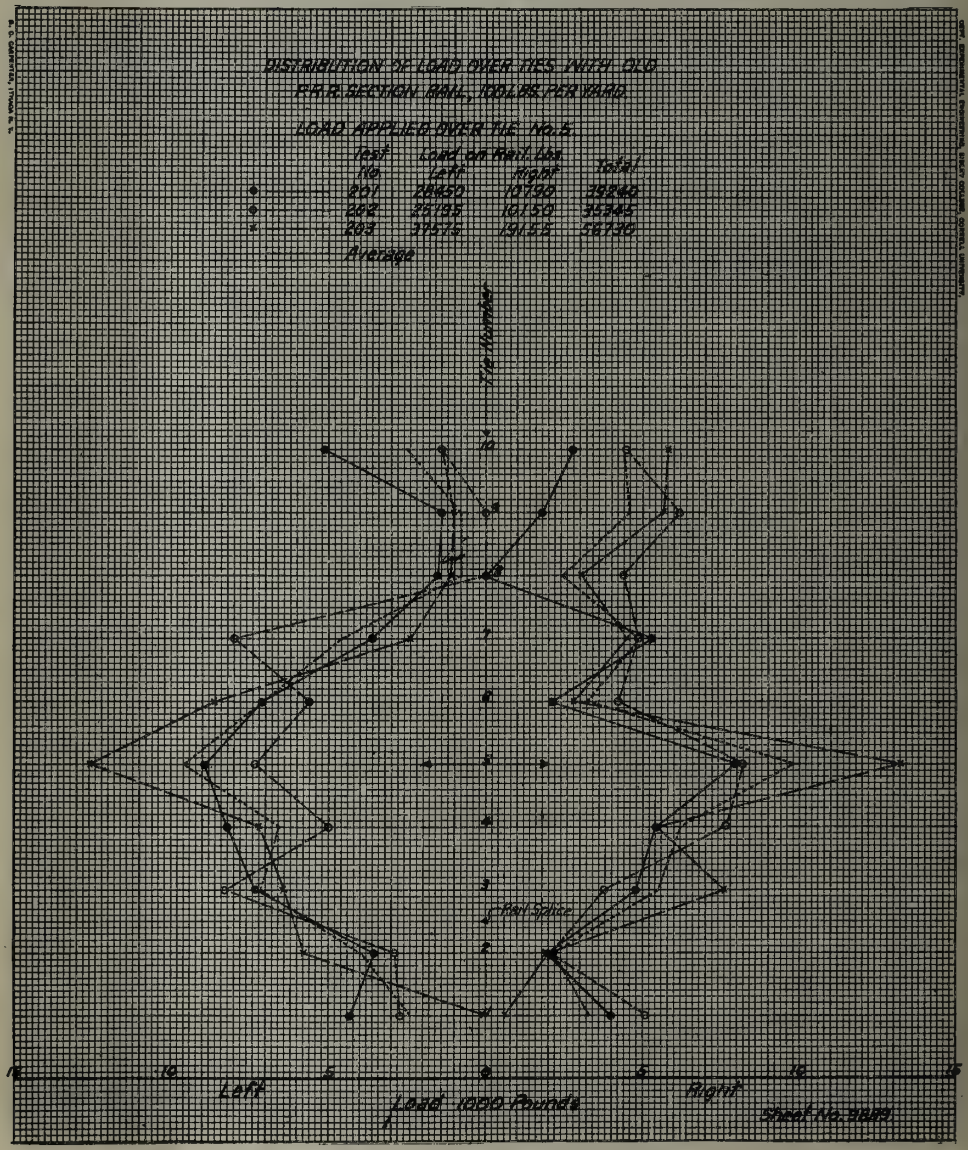
(Signed) C. D. Young,
Engineer of Tests.



P.R.R. RAIL SECTION 100 LBS. PER. YARD
DOTTED LINE SHOWS WORN RAIL IN TRACK WEST OF HOLLIDAYSBURG STA.
USED TO DETERMINE LOAD DISTRIBUTION OVER TIES.

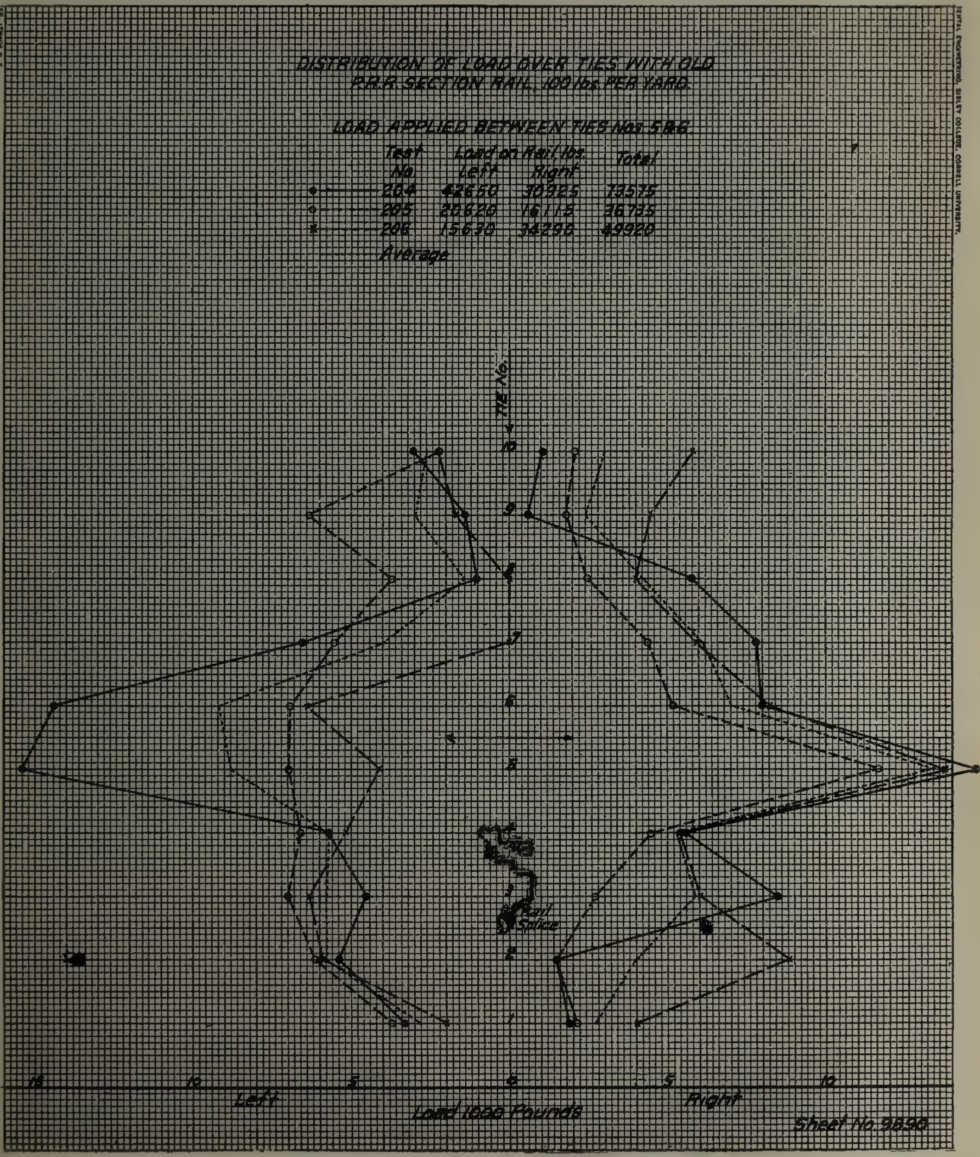
SHEET NO. 9886

Report No. 15-40.
April 1, 1915.



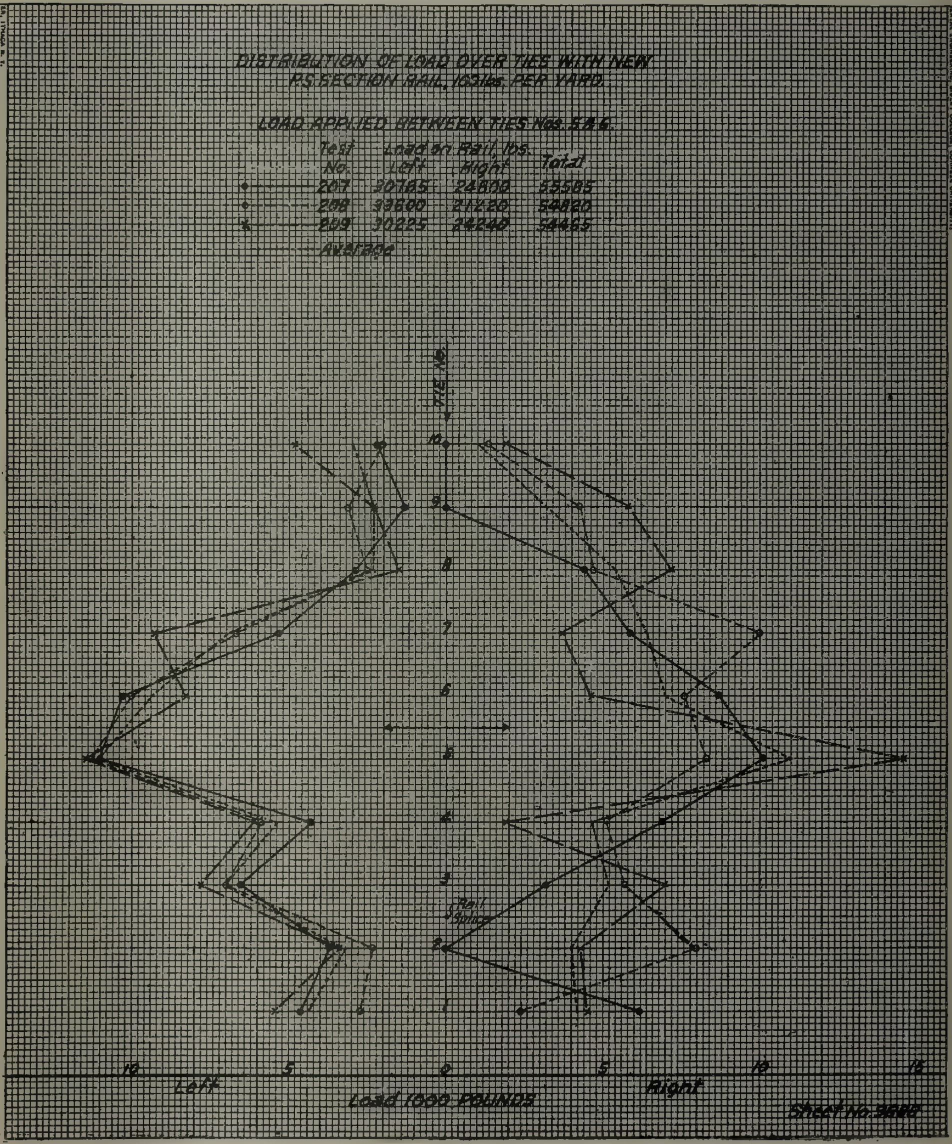
Distribution of Load Over Ties.

Report No. 15-40.
April 1, 1915.



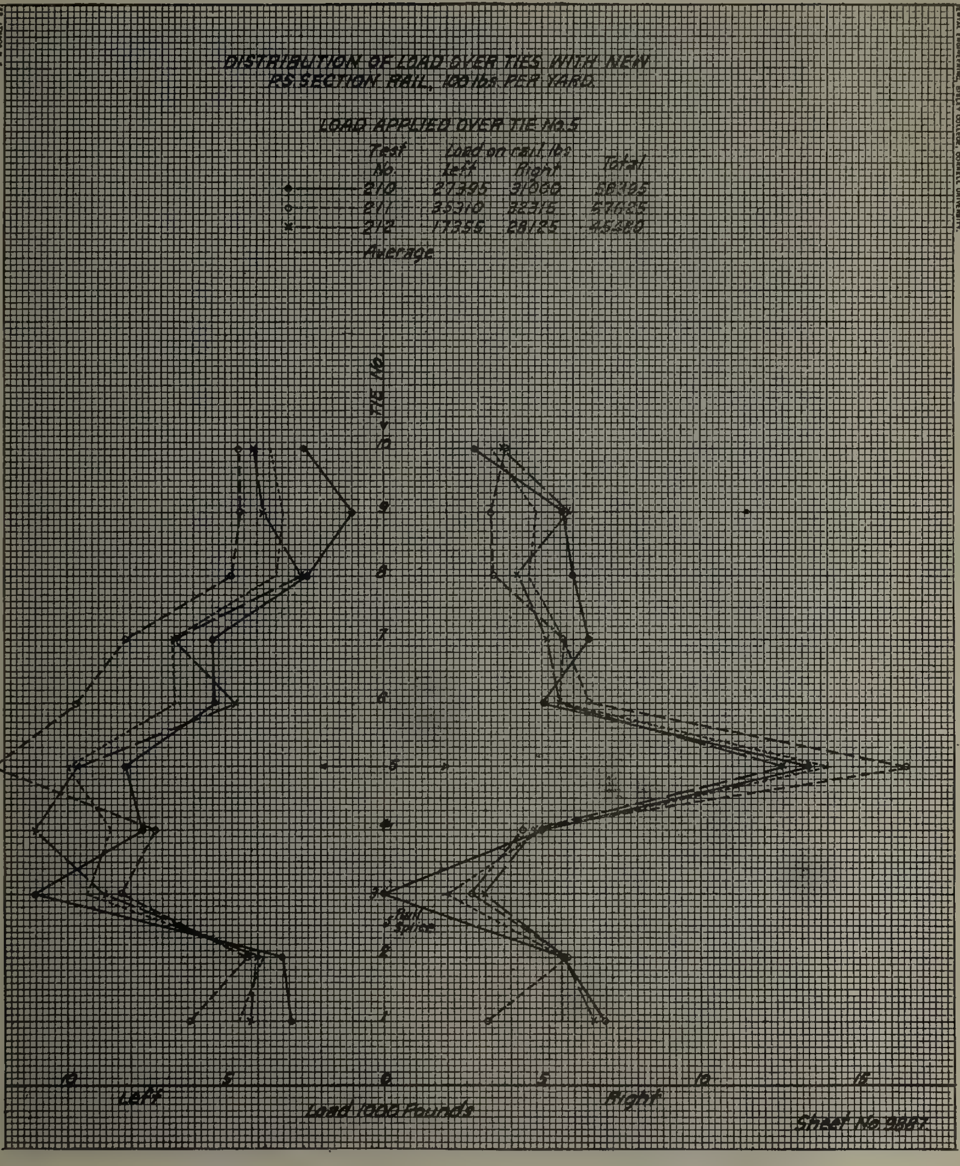
Distribution of Load Over Ties.

Report No. 15-40.
April 1, 1915.



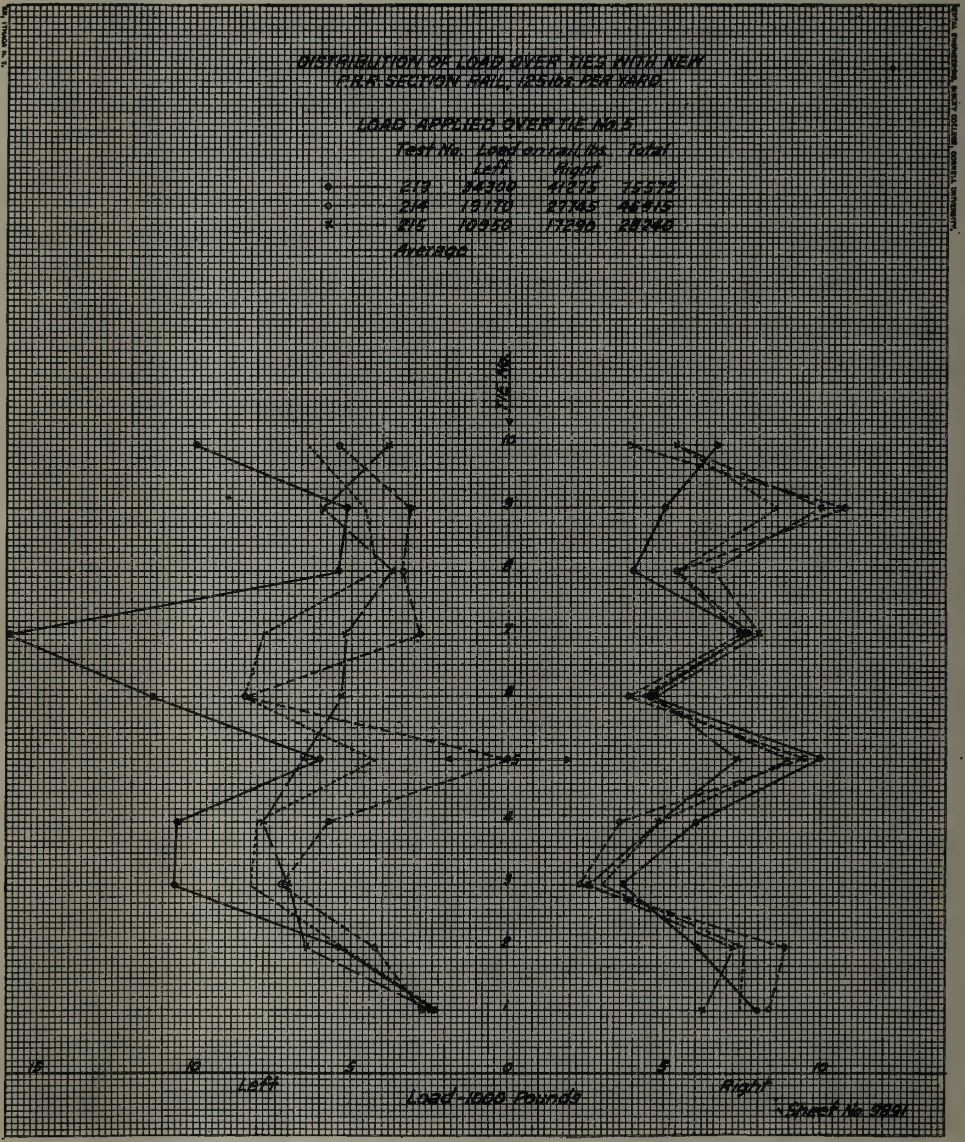
Distribution of Load Over Ties.

Report No. 15-40.
April 1, 1915.



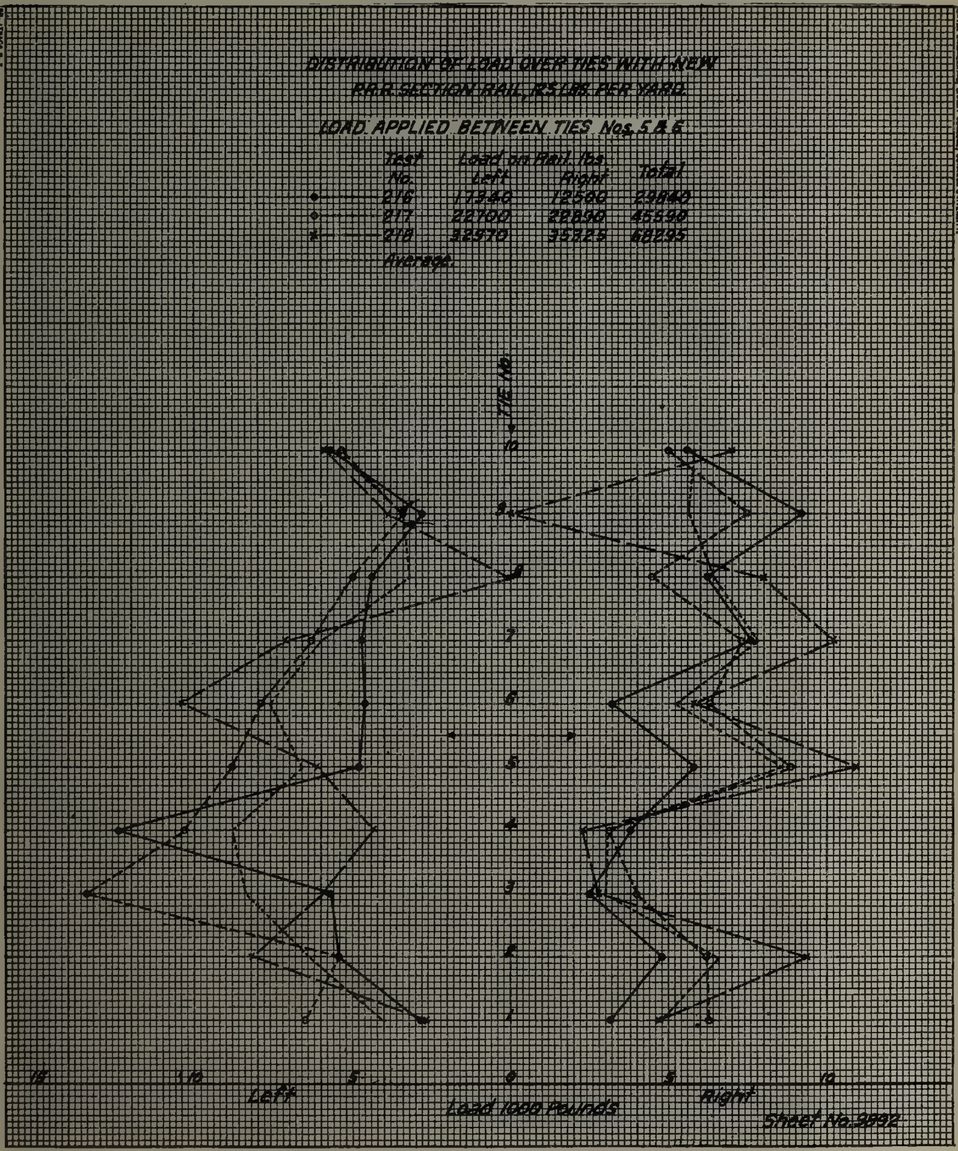
Distribution of Load Over Ties.

Report No. 15-40.
April 1, 1915.



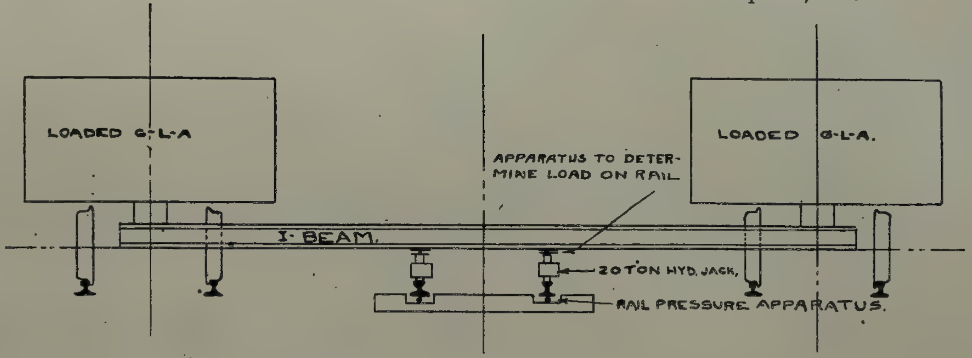
Distribution of Load Over Ties.

Report No. 15-40.
April 1, 1915.



Distribution of Load Over Ties.

Report No. 15-40.
April 1, 1915.



Distribution of Load Over Ties. No. 9924.

Test No.			Concentrated Load on Rail. Lb.	Load Recorded on Ties. Lb.	Ratio of Total Load o Ties to Concentrated Load.
201	100 Lb. Worn Rail	Load Over Tie 5	39240	86590	2.2
202			35345	92100	2.6
203			56730	96510	1.7
204		Load Bet. Ties 5 & 6	73575	115915	1.6
205			36735	93480	2.5
206			49920	100215	2.0
207	100 Lb. New Rail		55585	97355	1.7
208			54820	110785	2.0
209			54465	115895	2.1
210		Load Over Tie # 5	58395	105585	1.8
211			67625	125890	1.8
212			45480	117040	2.6
213	125 Lb. New Rail		75575	143965	1.9
214			46915	108235	2.3
215			28240	116920	4.1
216		Load Bet. Ties 5 & 6	29840	105415	3.5
217			45590	131330	2.9
218			68295	117665	1.7

Change made in the above table on April 29, 1915, as follows:-

Tests 201 to 206 inclusive made on worn rail instead of on new rail as specified on the original issue of this sheet and tests 207 to 212 inclusive made on new rail instead of on worn rail as specified on the original issue of this sheet.

DISTRIBUTION OF LOAD OVER TIES.

TEST DEPARTMENT.

Altoona, Pa., November 5, 1915.

Mr. J. T. Wallis,
General Superintendent Motive Power.

As requested by Mr. W. G. Coughlin, Engineer Maintenance of Way, in his letters to you of May 18, 1915, May 28, 1915, and June 4, 1915, tests were made to determine the distribution of load over ties, with various spacings and with 60, 70, 85, 100 and 125-lb. rails, when the loads on the rail were equal to the wheel loads and were distributed the same as that of a class "E6s" locomotive.

METHOD OF CONDUCTING TESTS.

2. The tests were conducted ⅛ mile west of New Portage Jct. passenger station on the Hollidaysburg Branch, on the track used for local traffic between that station and Duncansville.

3. Stretches of tracks were prepared of sufficient length so that the load on each tie and under each rail could be recorded for a distance equal to the length of the wheel base of a class "E6s" locomotive and for five ties beyond the foremost wheel of the engine truck and five ties behind the trailer wheels.

4. The weights of rails and the various tie spacings used in the tests are as follows:

Nominal Wt. of rail Lbs. per Yd.	*Length of rail, ft.*	*Ties per rail length.*
60	30	16
70	30	14-16
85	33	14-16-18
100	33	12-14-16-18
125	33	10-12-14-16

5. All the rails used in these tests had been worn to some extent in service, except the 125-lb. rails which were new. Worn rails of this latter type were not available for these tests. It is felt that the difference in the results that would be obtained with partially worn and with new rails would not be great enough materially to affect a comparison of the results obtained with the different weights of rails.

6. The actual weights of the rails used is shown in the following table; these weights were obtained from pieces cut from rails, selected at random, which had been used in making the tests:

Wt. per yard, Nominal.	*Pounds, Actual.*
60	58.7
70	68.2
85	81.9
100	97.5
125	124.5

7. In preparing the track, the ties were evenly distributed over the length of the rail, except the joint ties which were spaced twenty inches center to center. The rails were laid so that the splice on one side came midway between the splices on the opposite rail.

8. The ballast in the roadbed consisted of six inches of clean cinder below the bottom of the ties and six inches of mixed furnace slag and cinder below the clean cinder, the whole resting on a clay foundation.

9. The stretches of track were prepared two months previous to the start of the tests and during this time the roadbed received the attention that is usually given track of this character. From the time the stretches of track were prepared until the tests were made, frequent heavy rains were experienced, and we believe this aided in securing a firm foundation for the ties.

10. The devices used to record the load on the ties were the same as were used in previous tests, and are described in our report No. 15-12, dated February 24, 1915, except the devices on the three ties at each end of the test track, which differed from the devices placed on the other ties in that the load would be obtained from an impression made by one 1-inch ball instead of three 1-inch balls. This was done in order that a more accurate record of the light loads on the end ties would be obtained.

11. Locomotive No. 272, class "E6s", not under steam, was used to obtain the desired loading on the track. The boiler contained two gages of water and a medium bed of coal in the firebox, representing the condition of the locomotive in working order.

12. The locomotive was moved on to the track under test and placed so that the driving wheel came between the splices on adjacent rails. The locomotive was then raised by means of jacks so as to remove the weight from the rail. The impression plates were inserted in the recording devices and the locomotive was slowly lowered so that the full weight on all wheels was applied to the track simultaneously. The locomotive was allowed to remain in this position for a period of about two minutes and was then raised until the load was again removed from the rail.

13. In addition to the tests on cinder ballast track, a series of laboratory tests were made to determine the elastic limit and ultimate strength of the rails which had been used in the road tests. For these laboratory tests, pieces were cut from one of the rails of each weight and tested on supports spaced distances equal to the spacing of the ties.

14. Each piece of rail tested was placed transversely on the bed plate of the testing machine and supported by two supports having surfaces curved to a radius of 5 inches. The load was transmitted to the rail through a curved block located midway between the two supports. The loads were applied in increments and readings of the deflection and permanent set taken for each load until the permanent set was one inch; from this point the load was steadily applied until the rail was broken.

RESULTS OF ROAD TESTS.

15. The load imposed on each tie when the weight of the locomotive was placed upon the rails, is shown graphically on the following sheets:

Nominal Wt. of rail,		Ties per rail.				
Lbs. per yard		18	16	14	12	10
60	Sheet No.	.....	10434	.....	.....	.....
70	" "	.....	10435	10436	.....	.....
85	" "	10437	10438	10439	.....	.....
100	" "	10440	10441	10442	10443	.....
125	" "	.....	10444	10445	10446	10447

16. From the curves drawn for the 67 and 70-lb. rails it will be observed that generally the load obtained on the ties between the wheels was less than that obtained directly beneath the wheels. This is also true, but to a lesser extent, on the tests with 85-lb. rail, 18 ties per rail; 100-lb. rail, 12 and 18 ties per rail; and 125-lb. rail, 12 and 16 ties per rail. On the other tests with 85, 100 and 125-lb. rails the load placed on the rail by the engine truck and the driving wheels was more evenly distributed over the ties. The portions of the curves representing the

load on the ties back of the rear driving wheels show the same characteristics on all tests.

17. In some tests a greater load is shown on a tie located between the engine truck wheels or driving wheels than on a tie directly, beneath these wheels, examples of this kind being shown on sheet No. 10447, results of tests with 125-lb. rail, 10 ties per rail.

18. The maximnm load on a tie due to the weight on the trailer truck was usually recorded on the tie in front of the point at which the load was applied.

19. On sheets Nos. 10448 and 10449 the rail is considered as one continuous beam, and average curves of the distribution of load over the ties for the different weights of rails and the tie spacing are shown. The curves on these sheets have been obtained from averages computed from the results of the load on each tie, for all of the tests made under the same conditions. The load supported on each tie under the rail on one side of the track is considered as being one-half of the total load on the tie.

RESULTS OF LABORATORY TESTS.

20. The deflection and permanent set of the different weights of rails when placed on supports with various spacings, is shown on sheets Nos. 10460 to 10465, inclusive.

21. The elastic limits were determined from curves of the deflection of the rails at various loads which have been plotted to a magnified scale and are shown on sheets Nos. 10466 to 10468, inclusive. The elastic limit for each weight of rail and spacing between supports has been taken as being the point on the curve where marked deflection from the initial slope of the curve first takes place.

CONCLUSIONS.

22. The following table shows the maximum load obtained on a tie under the locomotive for each plan of track construction used in making the road tests. These figures are averages computed from the sum of the loads on each tied for all of the tests of a like condition:

Nominal Wt. of rail lbs. per yard.	*No. ties per rail length.*	*Max. load, on ties, lbs.*
60	16	28,620
70	14	29,750
"	16	28,990
85	14	25,020
"	16	24,260
"	18	26,620
100	12	33,220
"	14	27,060
"	16	22,720
"	18	23,400
125	10	35,720
"	12	30,920
"	14	26,700
"	16	24,680

23. No direct comparison can be made of this table or of the average curves shown on sheets Nos. 10448 and 10449, owing to the change in the location at which the readings were taken in respect to a given point of the locomotive. However, it can be seen from these average curves and the above figures that when a decrease is made in the number of ties in a given space the load supported on each tie is increased and, further, that the weight of rail used has also an influence on the distribution of

the load over the ties. This is also shown o nsheet No. 10451, p. 221, which gives the per cent. of the total number of readings which showed loads less than or over a given amount for each condition of track construction.

24. In addition to the increase in the load supported on each tie due to a decrease in the number of ties in the track; the ratio between the weight of the locomotive and the total load recorded on the track shown on sheet No. 10450, p. 220, indicates that when this decrease in the number of ties is made, a further increase of the load to be supported on each tie can be expected because of the yielding of the track structure which causes the rail to create a lever action over the ties.

25. In those cases where the total load on the track was less than the weight of the locomotive, it is assumed that a portion of the locomotive weight was supported on the ties beyond the points at which readings were taken.

26. The loads determined as being the elastic limits have been plotted on sheet No. 10469 and curves drawn for each weight of rail showing the elastic limits when the rail supports are at various distances from each other. In a similar manner curves have been obtained for the ultimate strength of each weight of rail and are shown on sheet No. 10470. These curves show that as the distances between the ties is decreased there will be an increase in the amount of load that the rail will be able to support before it is loaded beyond its strength. This is not caused by any increase in the strength of the rail itself, but is due to a decrease in the bending moment which occurs when the ties are spaced nearer to each other.

27. A comparison of the elastic limits and ultimate strengths of different weights of rails with various spacings between supports is made on sheet No. 10471, p. 230. The results obtained with tests of 100-lb. rail and supports spaced 22.25 in. is based at 100 per cent. and the results obtained for the other tests are compared with this same basis.

28. These tests, in accordance with your request, were made with class E6s locomotive, which is one of our heavier types of existing locomotives, and the loads on the ties were applied very slowly, practically representing static conditions. We therefore do not feel that the maximum figure shown represents that which will be obtained when our modern locomotives are passing over track in similar condition as our previous tests reported to you indicate that speed, as well as axle load, is a contributory factor in the amount of load which is sustained by the tie.

(Signed) C. D. YOUNG,
Engineer of Tests.

RATIO BETWEEN THE WEIGHT OF THE LOCO. AND THE TOTAL LOAD RECORDED ON THE TEST TRACK.

Wt. of rail	No. ties per rail	Test No.	Load Recorded, Pounds			Total load recorded,% of Wt. of loco.
			Right rail	Left rail	Total	
60	16	407	140970	119355	260325	107
"	"	408	134165	128690	262855	108
"	"	409	137720	122360	260080	107
70	16	410	143310	121915	265225	109
"	"	411	135780	122910	258690	106
"	"	412	133410	121770	255180	105
70	14	422	147435	140340	287775	118
"	"	423	139690	141425	281115	115
"	"	424	135465	141040	276505	113
85	18	404	142315	129330	271645	111
"	"	405	135545	128510	264055	108
"	"	406	141975	130640	272615	112
85	16	419	139110	135645	274755	113
"	"	420	140845	132795	273640	112
"	"	421	129370	129960	259330	106
85	14	441	129790	133225	263015	108
"	"	442	137180	133605	270785	111
"	"	443	131815	136315	268130	110
100	18	401	116180	129885	246065	101
"	"	402	132075	116410	248485	102
"	"	403	136715	117250	253965	104
100	16	413	125540	128535	254075	104
"	"	414	115790	121865	237655	98
"	"	415	114165	115625	229790	94
100	14	425	138230	135085	273315	112
"	"	426	125355	139510	264865	109
"	"	427	129510	147015	276525	113
100	12	431	144690	121130	265820	109
"	"	432	138600	117165	255765	105
"	"	433	126995	134715	261710	107
125	16	416	113455	101925	215380	88
"	"	417	125935	104690	230625	95
"	"	418	118490	108590	227080	93
125	14	428	130885	133475	264360	108
"	"	429	123775	130910	254685	105
"	"	430	125095	124985	250080	103
125	12	434	130965	146720	277685	114
"	"	435	130285	148525	278810	114
"	"	436	127435	140475	267910	110
125	10	437	116515	120035	236550	97
"	"	440	135850	126110	261960	108
"	"	444	136285	131405	267690	110

Weight of locomotive = 243670 pounds.

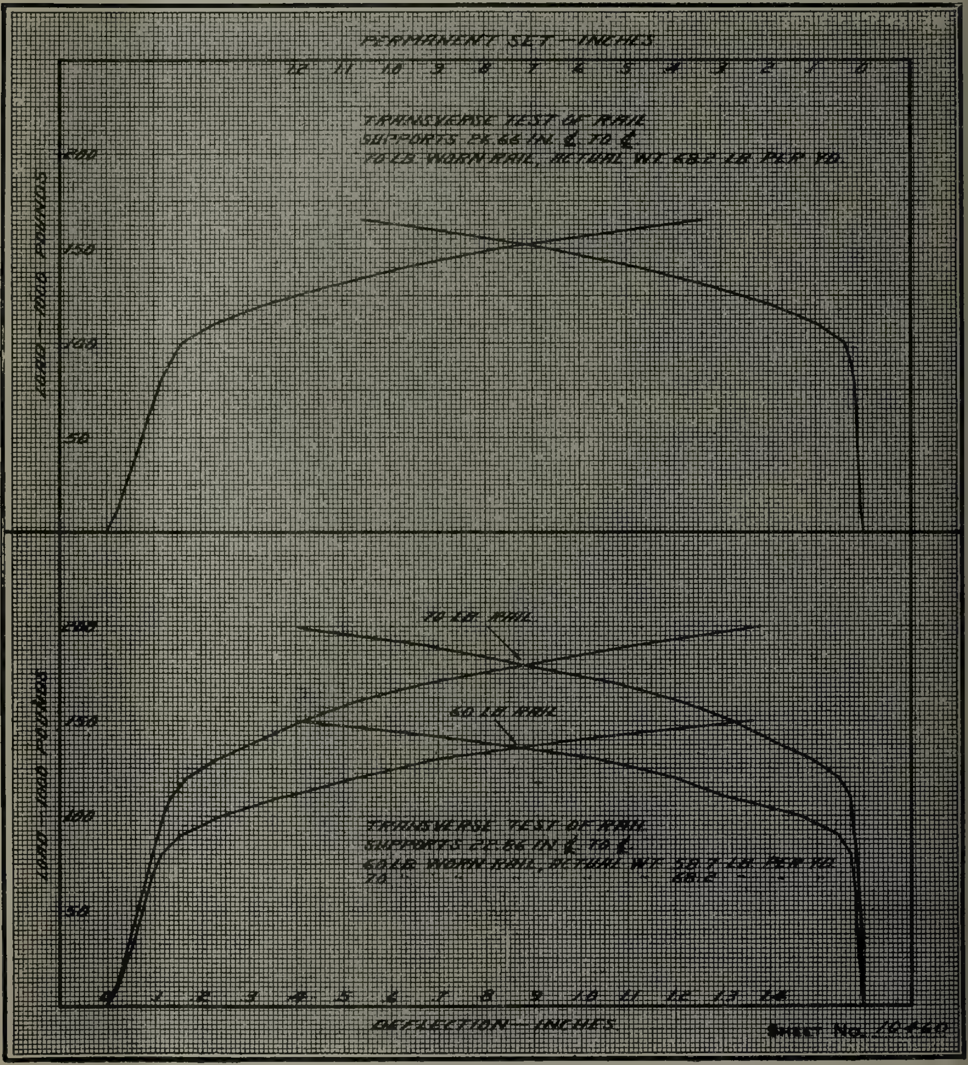
SHEET No. 10450.

PER CENT. OF READINGS LESS THAN OR OVER GIVEN AMOUNTS FOR TESTS MADE WITH EACH KIND OF RAIL AND TIE SPACING.

Weight of rail,			60 #	70 #		85 #		
No. of ties per rail,			16	14	16	14	16	18
% of readings								
Less than	5000	Lbs.	60.3	50.7	66.0	53.6	48.7	49.4
Over	5000	"	39.7	49.3	34.0	46.4	51.3	50.6
"	10000	"	15.4	18.1	16.0	21.0	15.3	7.8
"	15000	"	0.6	4.9	3.8	3.6	0.7	1.9
"	20000	"	0	0.7	0	0	0	0

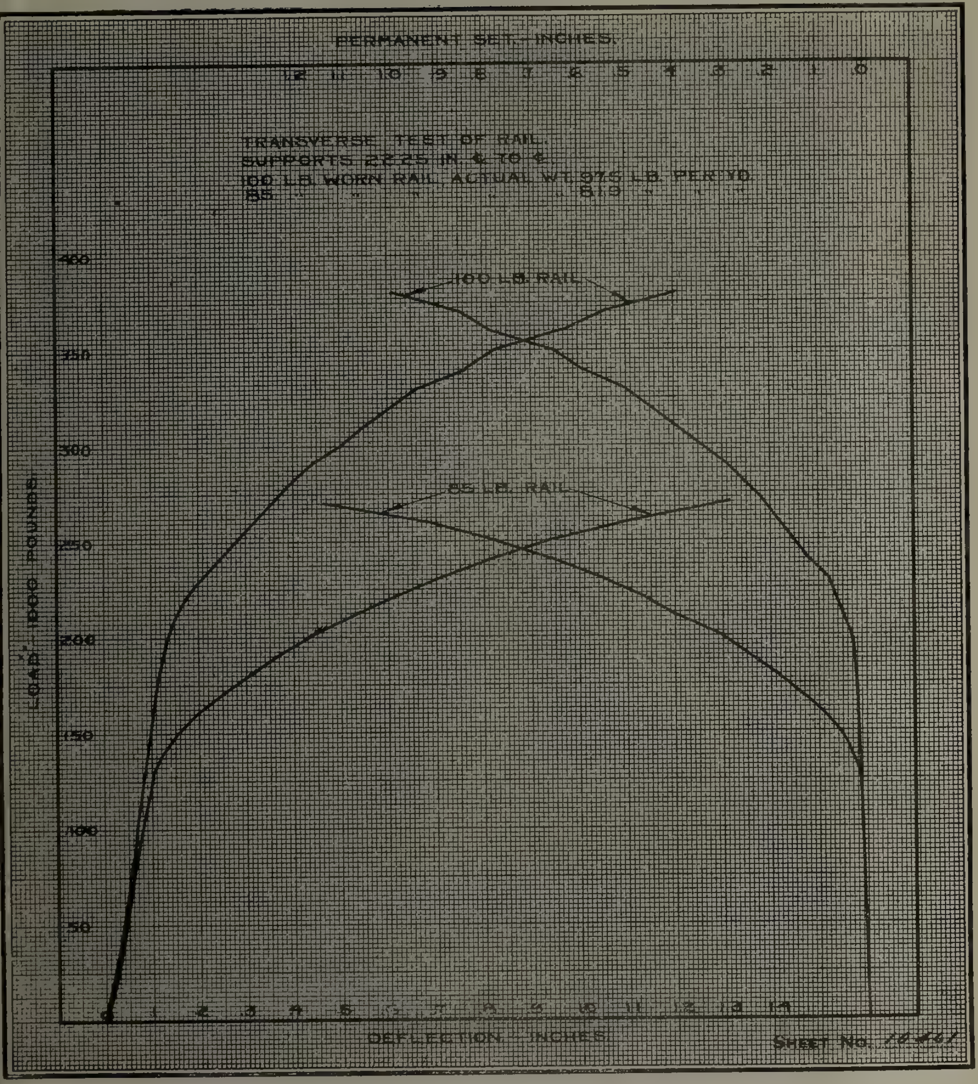
Weight of rail,			100 #				125 #			
No. of ties per rail,			12	14	16	18	10	12	14	16
% of readings										
Less than	5000	Lbs.	50.0	53.6	55.3	64.1	50.0	46.1	51.5	62.7
Over	5000	"	50.0	46.4	44.7	35.9	50.0	53.9	48.5	37.3
"	10000	"	23.8	18.1	14.0	10.9	36.1	23.8	17.4	10.0
"	15000	"	4.8	4.3	0	0.6	13.0	7.9	2.2	0
"	20000	"	1.6	0	0	0	0.9	0.8	0	0

Report No. 15-102.
October 22, 1915.



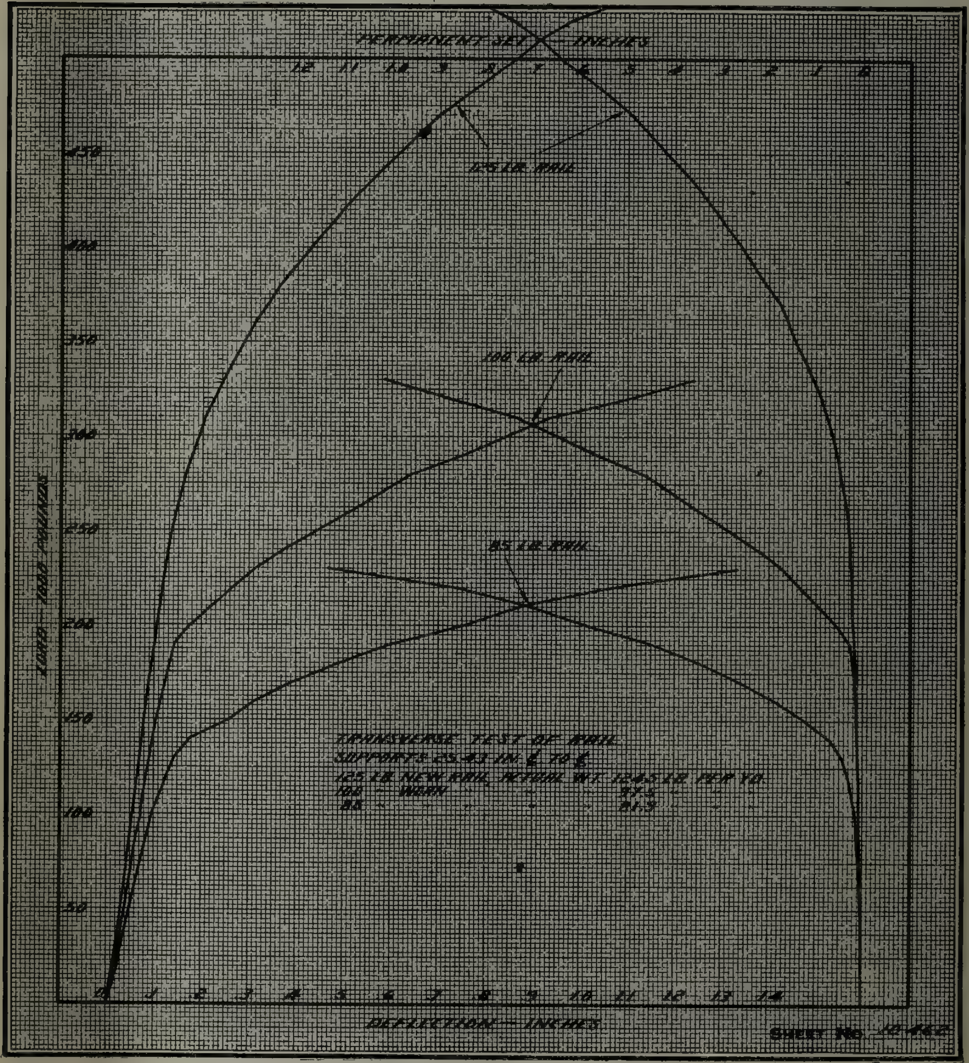
Distribution of Load Over Ties.

Report No. 15-102.
October 22, 1915.



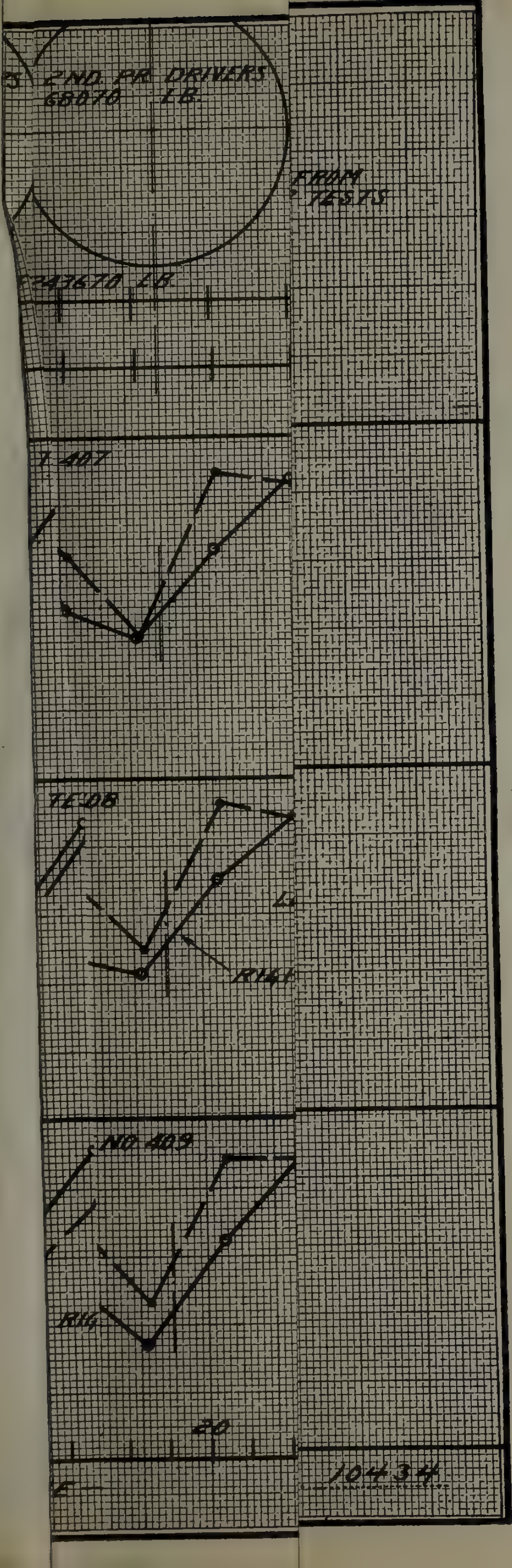
Distribution of Load Over Ties.

Report No. 15-102.
October 22, 1915.

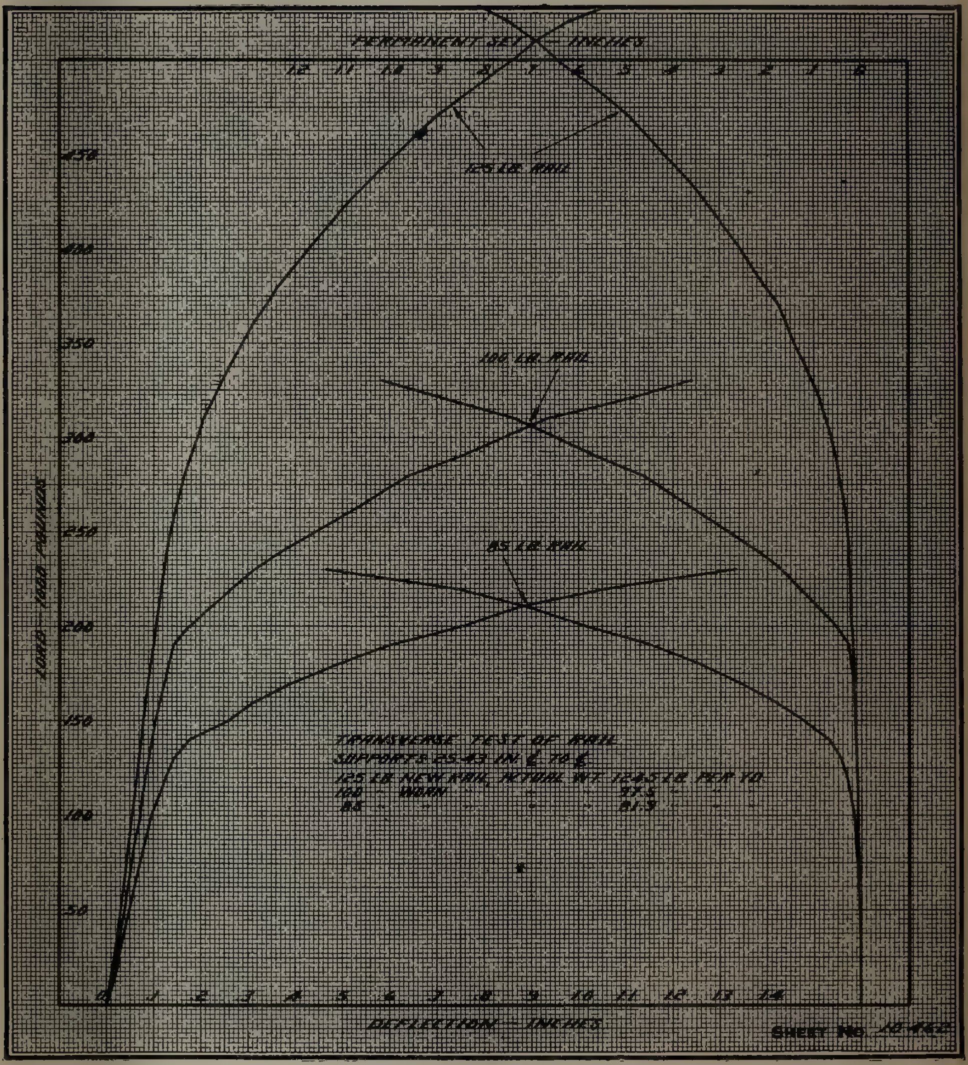


TRANSVERSE TEST OF RAIL
SUPPORTS 25.43 IN. ℄ TO ℄
125 LB. NEW RAIL, ACTUAL WT. 124.5 LB. PER YD.
100 — WORN " " " 97.5 " " "
85 " " " " 81.9 " " "

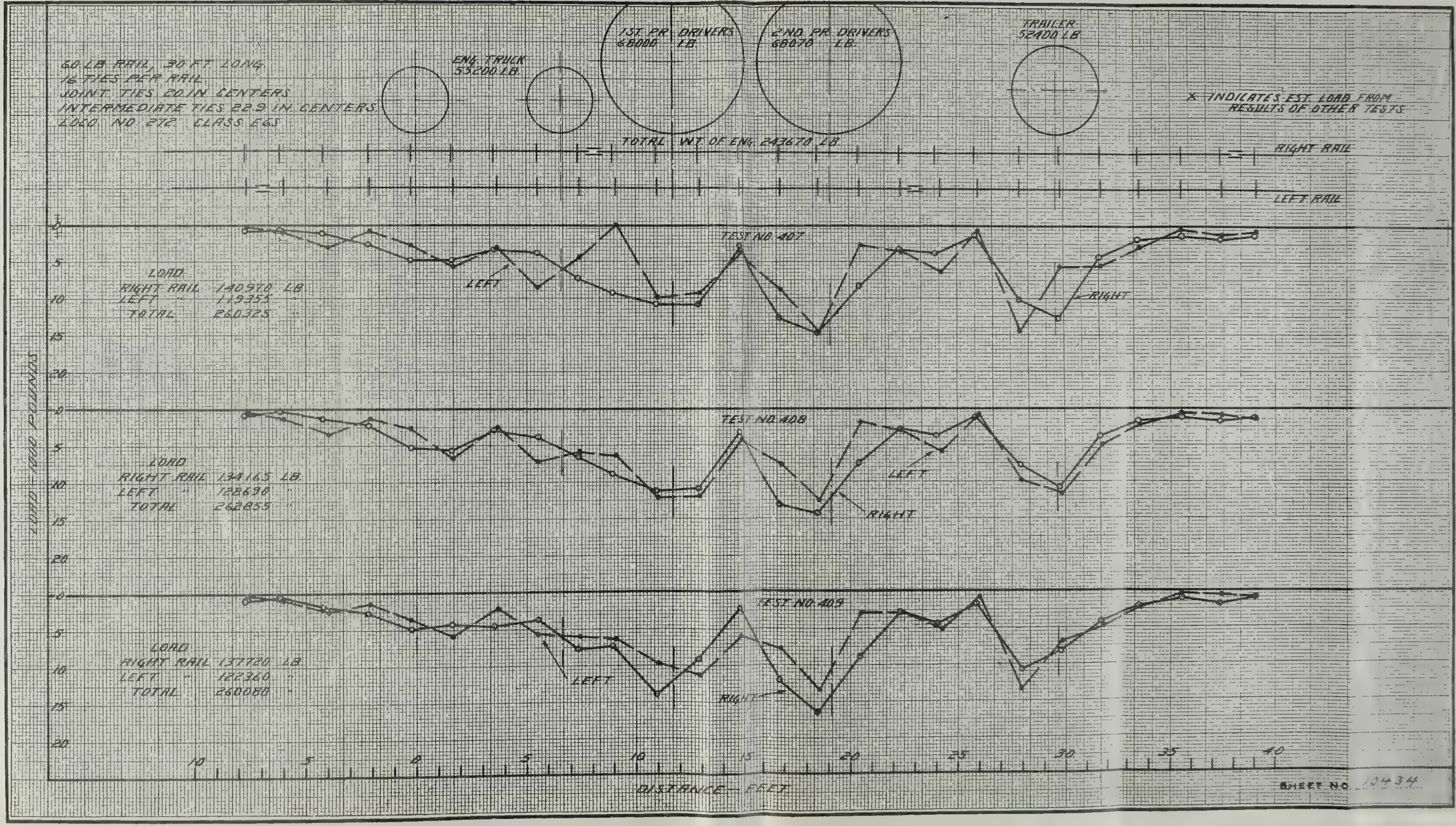
Distribution of Load Over Ties.


2ND. PR. DRIVERS
68870 LB.
FROM
TESTS
243670 LB.
T. 407
TE 08
L
RIGH
NO. 409
RIG.
20
E
10434

Report No. 15-102.
October 22, 1915.



Distribution of Load Over Ties.


60 LB RAIL, 30 FT LONG
16 TIES PER RAIL
JOINT TIES 20 IN CENTERS
INTERMEDIATE TIES 22.9 IN. CENTERS.
LOCO. NO. 272 CLASS E6S
ENG. TRUCK 53200 LB.
1ST. PR. DRIVERS 68000 LB
2ND. PR. DRIVERS 68070 LB.
TRAILER 52400 LB.
TOTAL WT. OF ENG. 243670 LB.
X INDICATES EST. LOAD FROM RESULTS OF OTHER TESTS
RIGHT RAIL
LEFT RAIL
TEST NO. 407
LOAD
RIGHT RAIL 140970 LB.
LEFT " 119355 "
TOTAL 260325 "
LEFT
RIGHT
TEST NO. 408
LOAD
RIGHT RAIL 134165 LB.
LEFT " 128690 "
TOTAL 262855 "
LEFT
RIGHT
TEST NO. 409
LOAD
RIGHT RAIL 137720 LB.
LEFT " 122360 "
TOTAL 260080 "
LEFT
RIGHT
LOAD—1000 POUNDS
0
5
10
15
20
10
5
0
5
10
15
20
25
30
35
40
DISTANCE—FEET
SHEET NO. 10434

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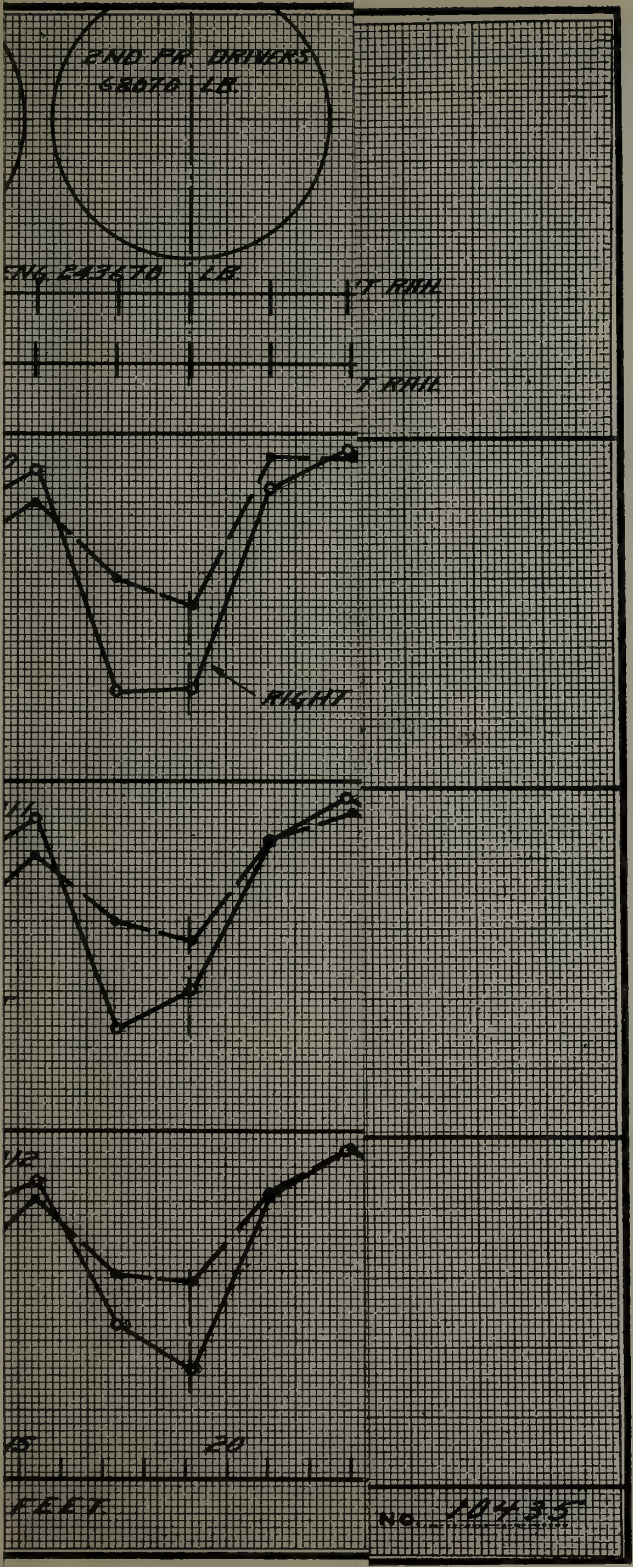
2ND PR. DRIVERS
65070 LB.
NG. 243470 LB.
T RAIL
T RAIL
RIGHT
15
20
FEET
NO. 10435

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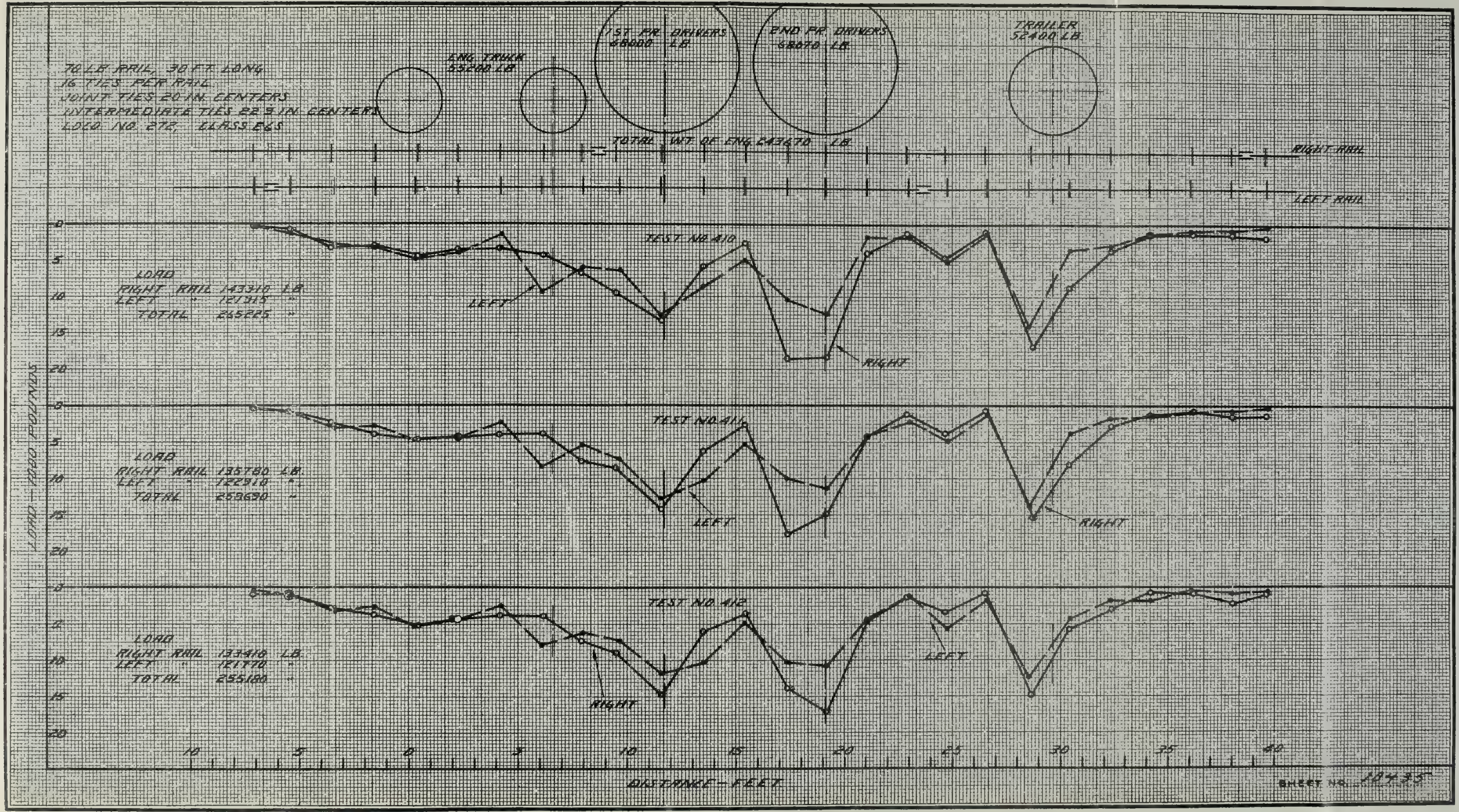

Distribution of Load Over Ties

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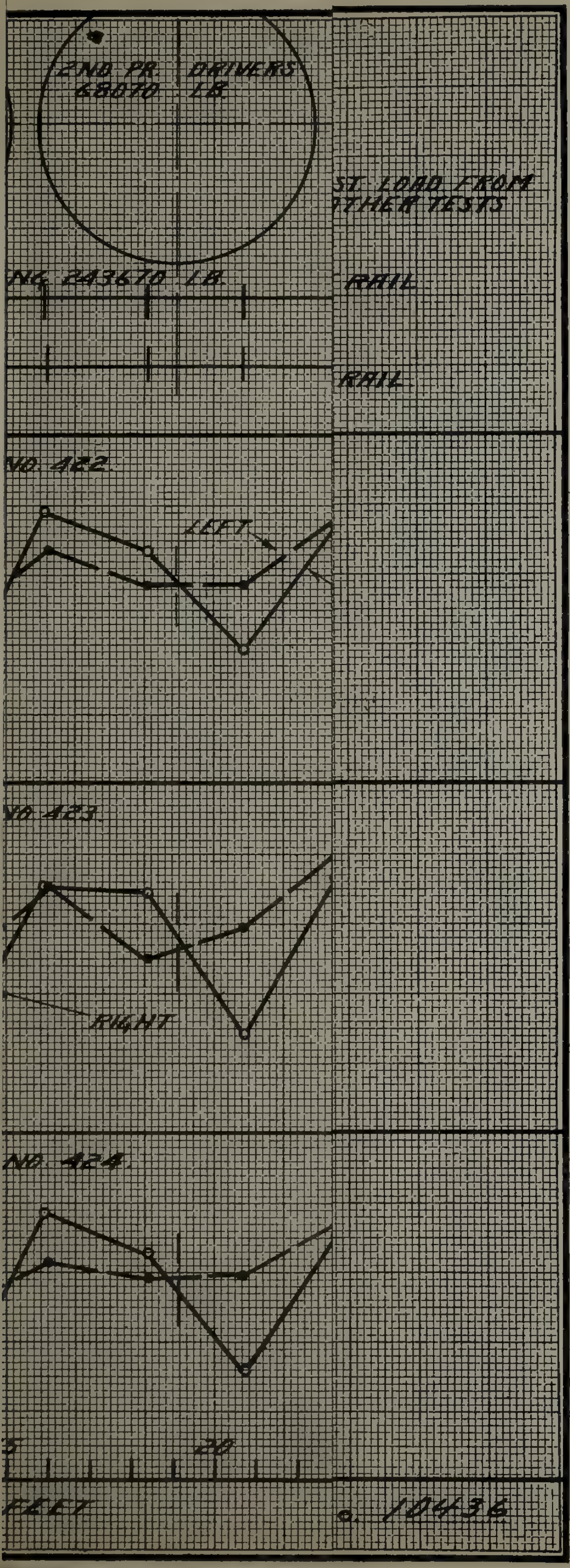
2ND. PR. 68070
DRIVERS LB.
ST. LOAD FROM
THER TESTS
NG. 243670 LB.
RAIL
RAIL
NO. 422.
LEFT
NO. 423.
RIGHT
NO. 424.
5
20
FEET
o. 10436

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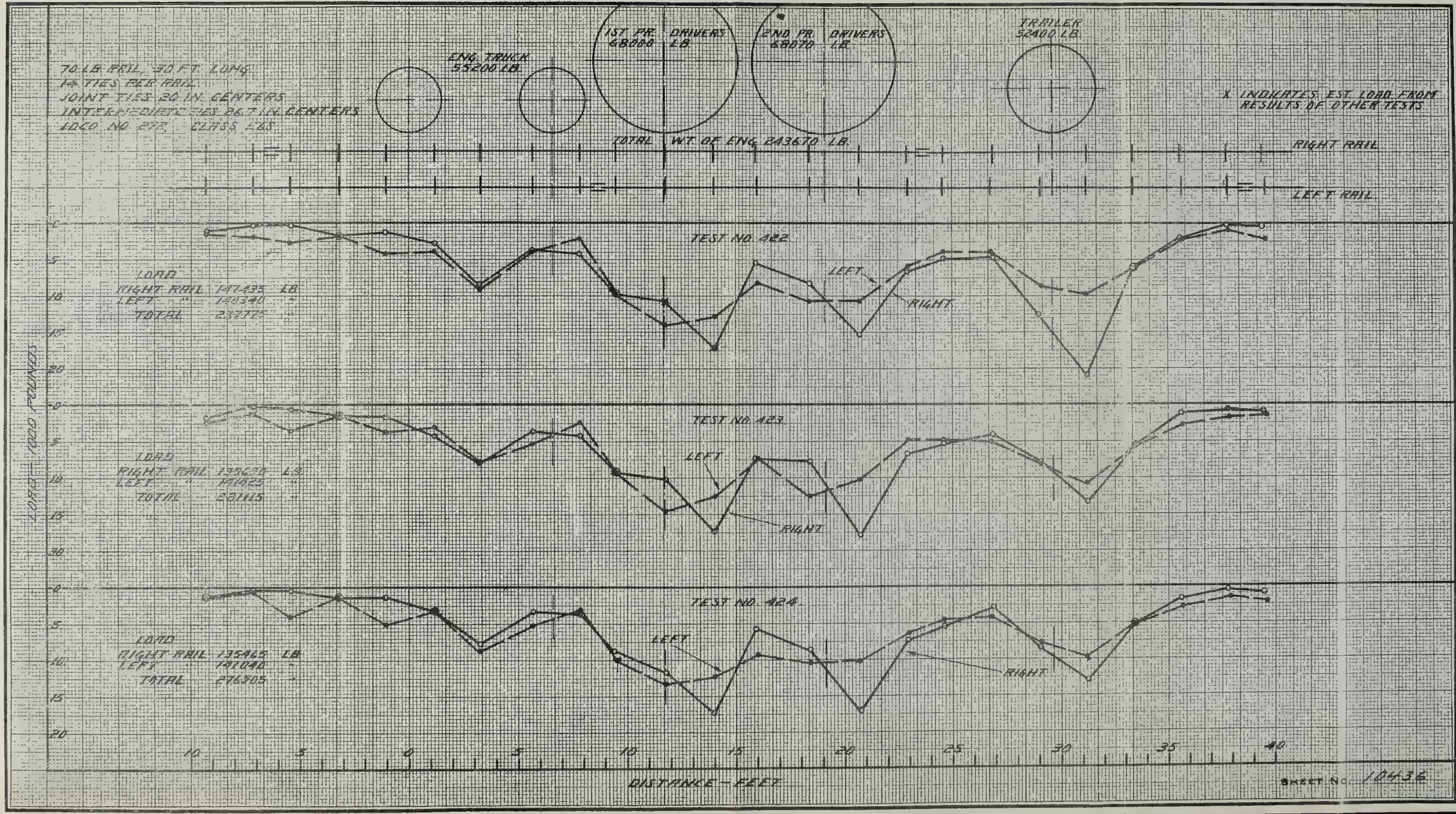
Report No. 15-102.
October 7, 1915.



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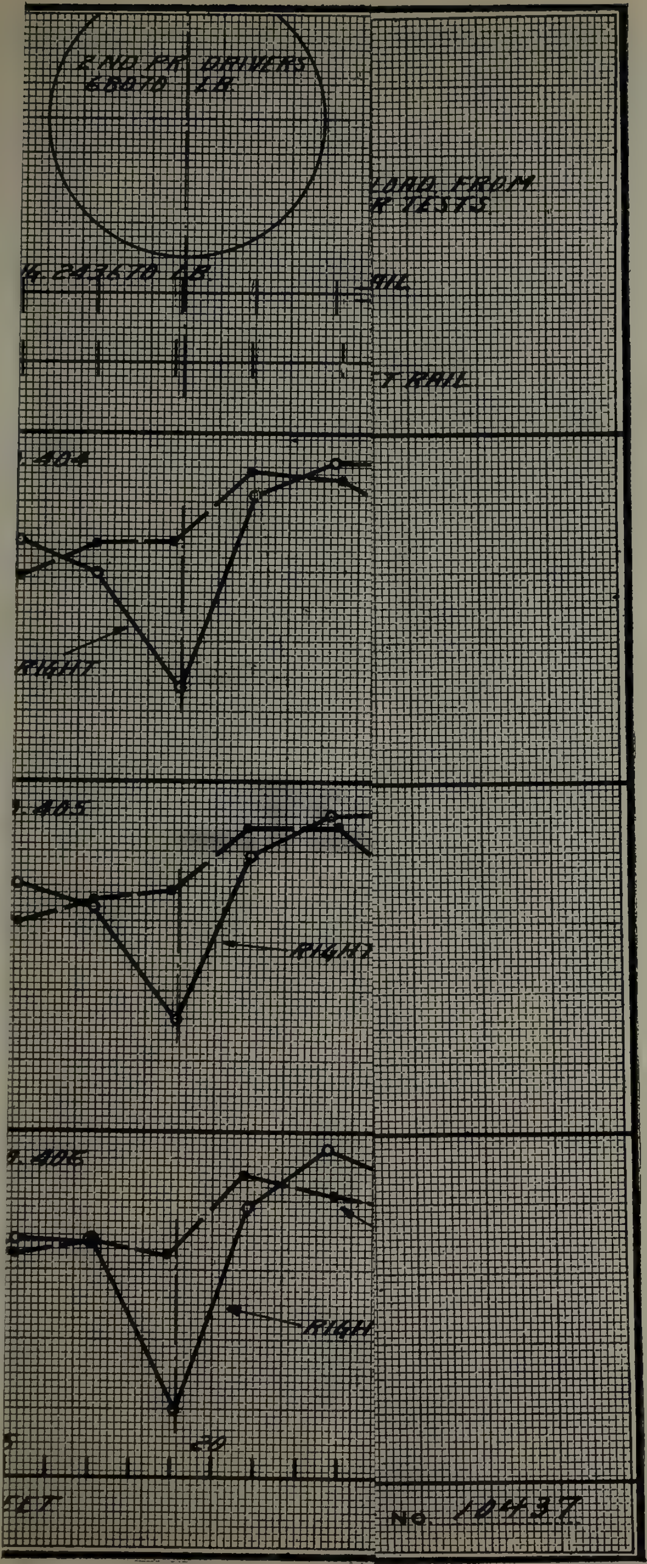
2 ND PR. DRIVERS
68870 LB.
4.243670 LB.
OAD FROM
R TESTS
AIL
T RAIL
.404
RIGHT
.405
RIGHT
.406
RIGH
20
EET
NO. 10437

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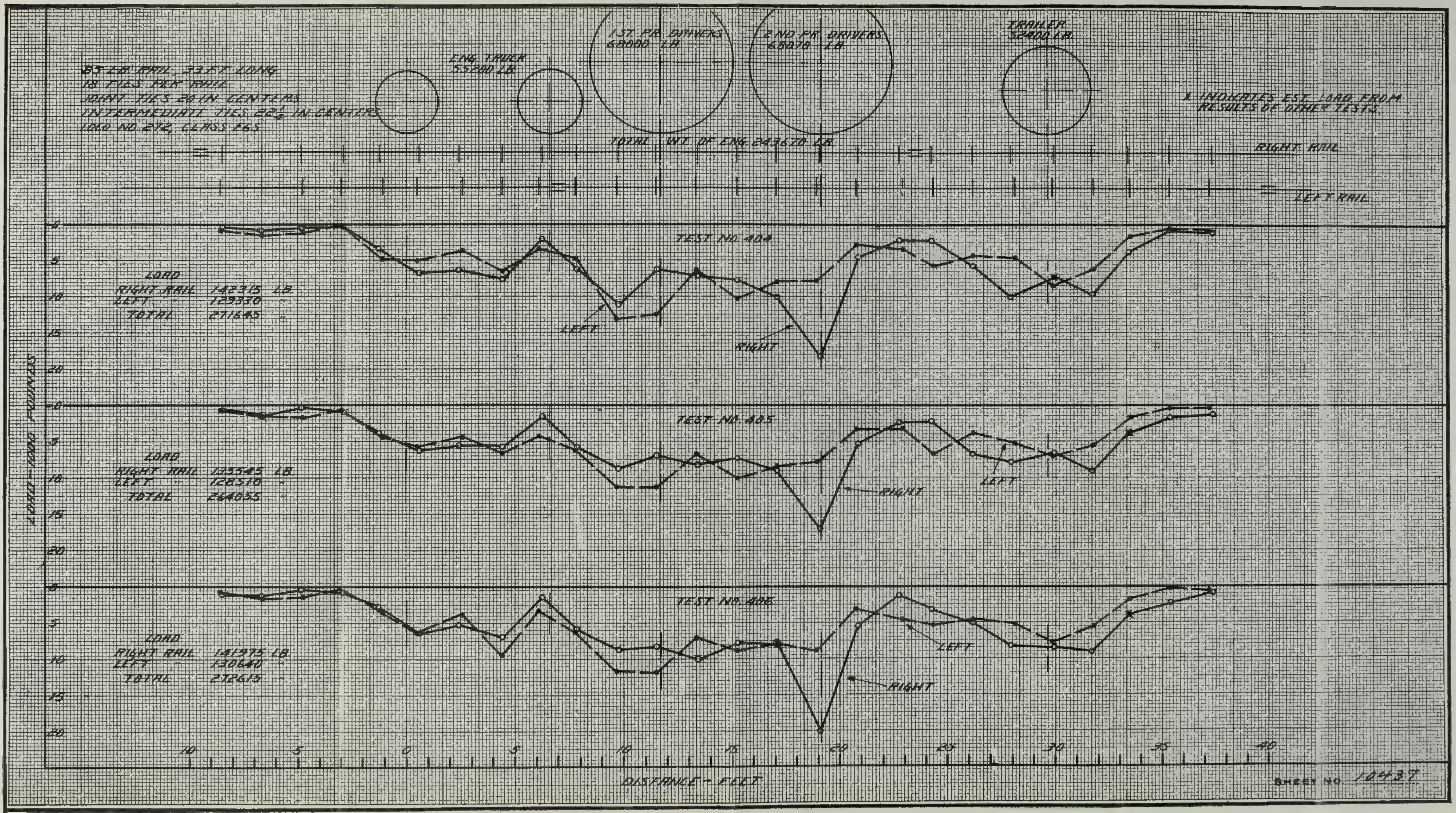
Report No. 15-102
October 7, 1915.



Distribution of Load Over Ties.

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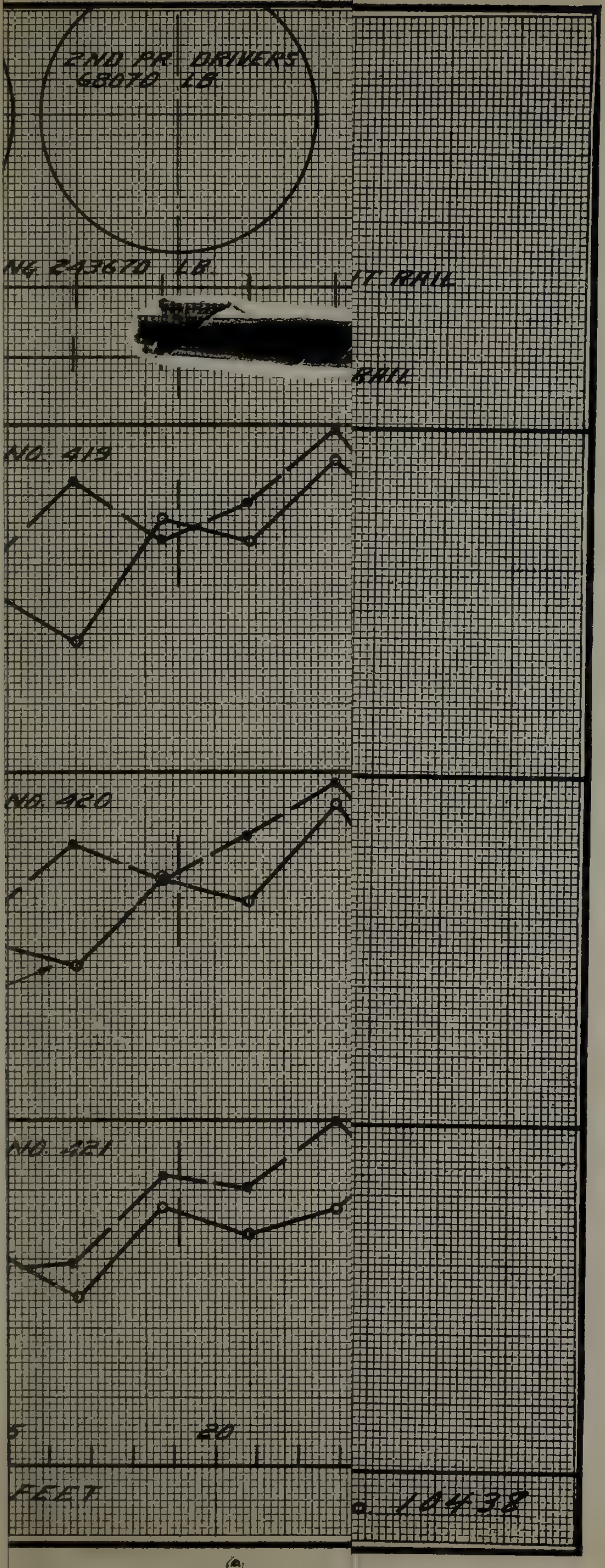
2ND PR. DRIVERS
68670 LB.
NG. 243670 LB.
LT. RAIL
RAIL
NO. 419
NO. 420
NO. 421
5
20
FEET
o. 14438

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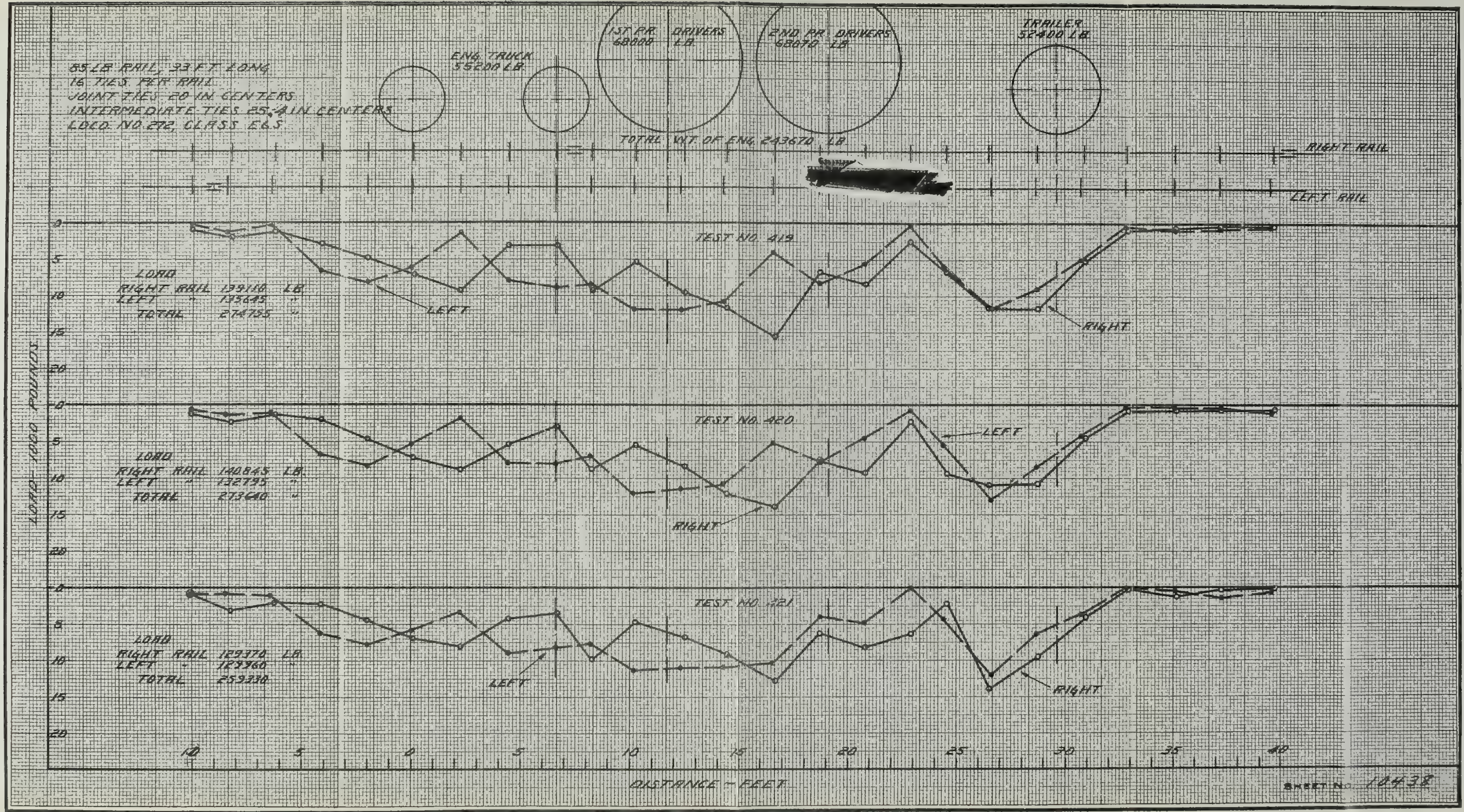

Distribution of Load Over Ties.

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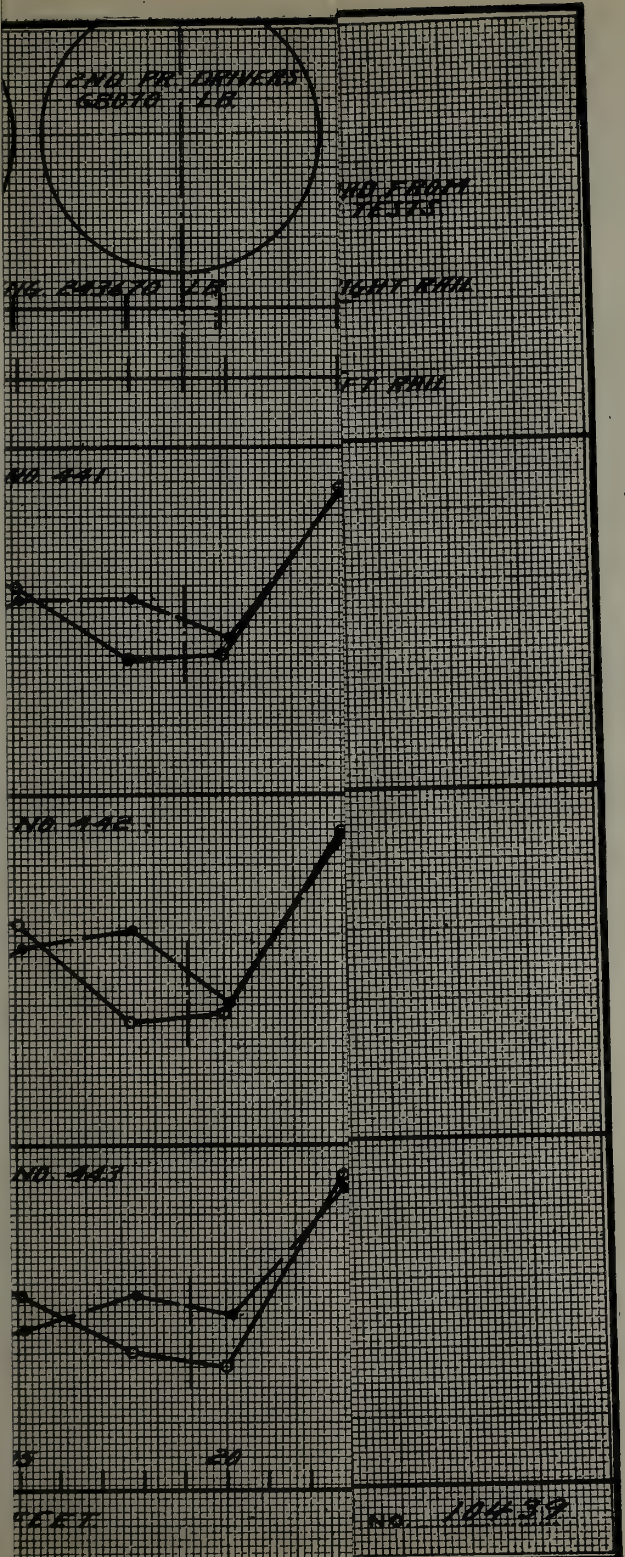
2ND PR. DRIVERS
65070 LB
HD FROM
TESTS
NG 243470 LB
IGHT RAIL
FT RAIL
NO. 441
NO. 442
NO. 443
15
20
FEET
NO. 10439

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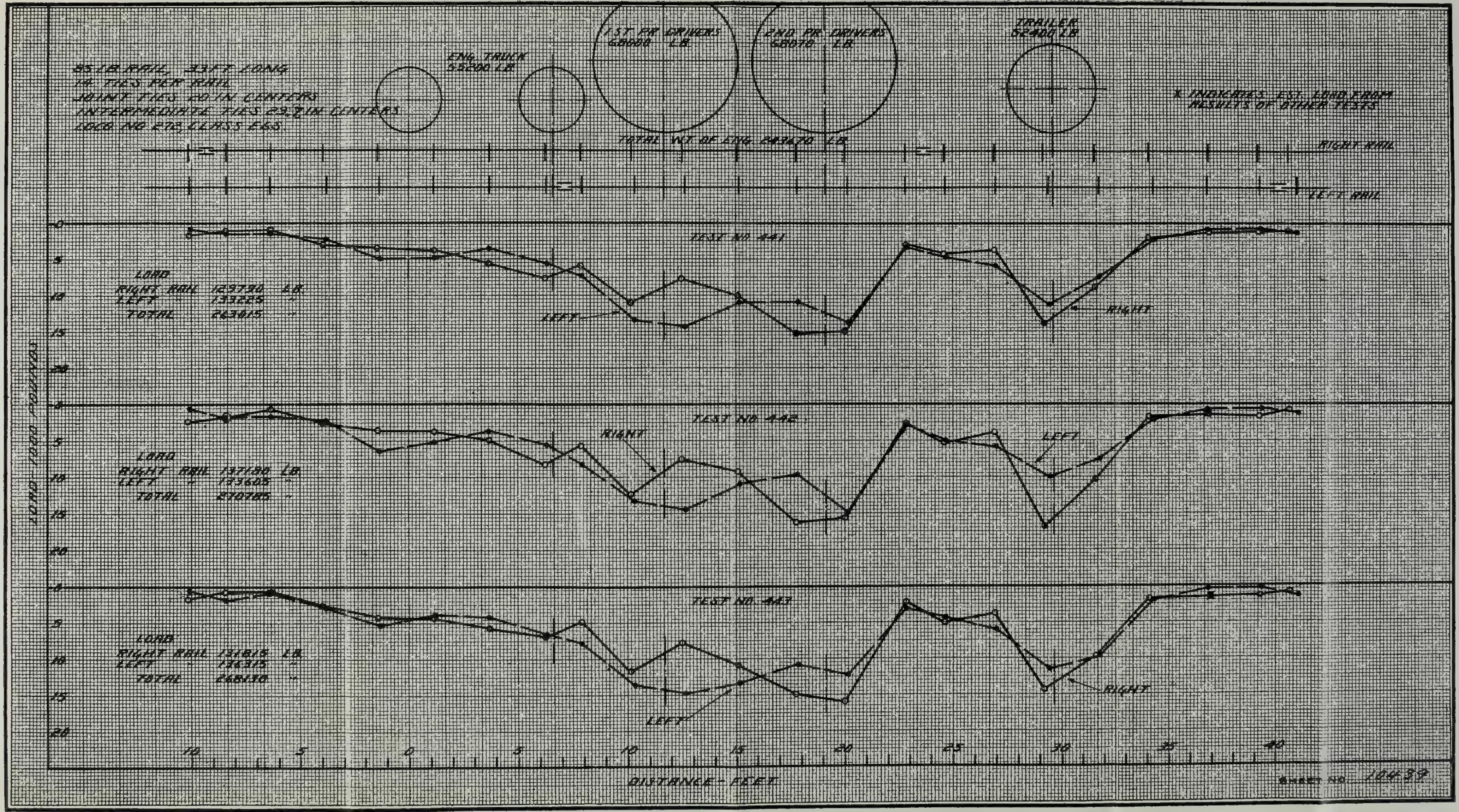

Distribution of Load Over Ties.

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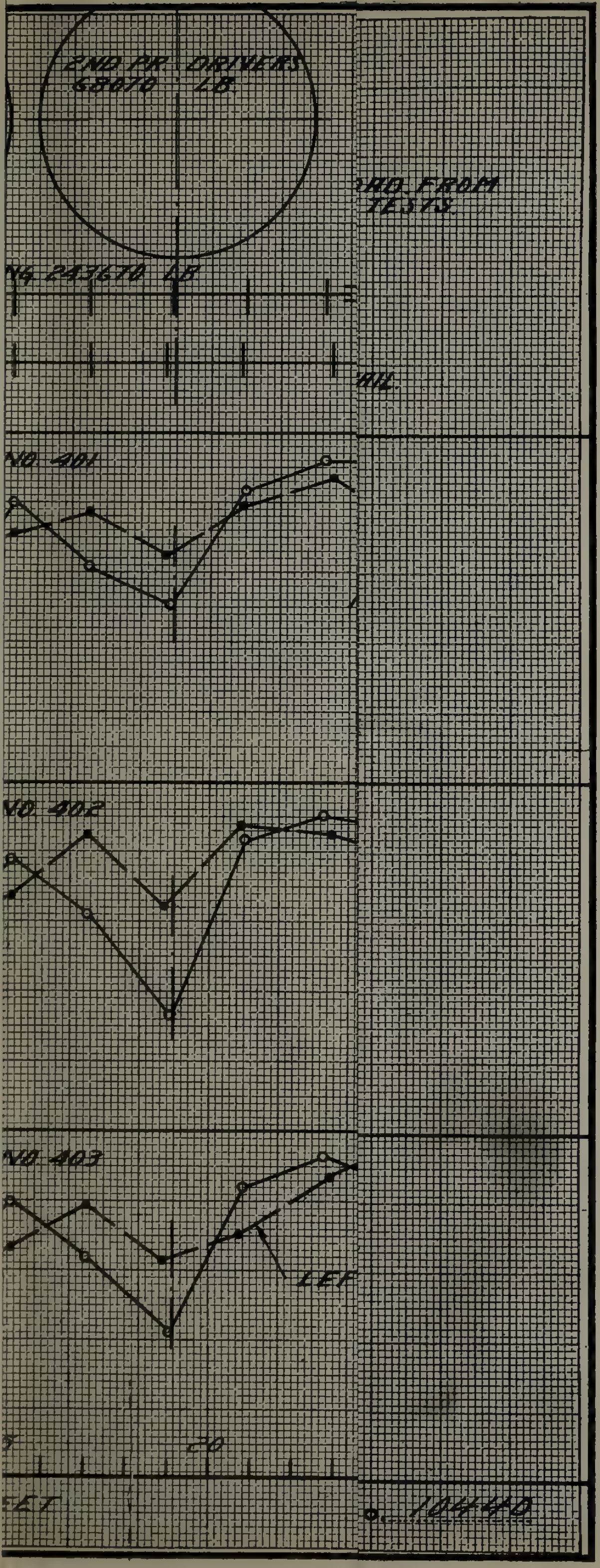
2ND PR. DRIVERS
68070 LB.
RD. FROM
TESTS.
NG. 243670 LB.
RAIL.
NO. 401
NO. 402
NO. 403
LEF
20
EET.
104440.

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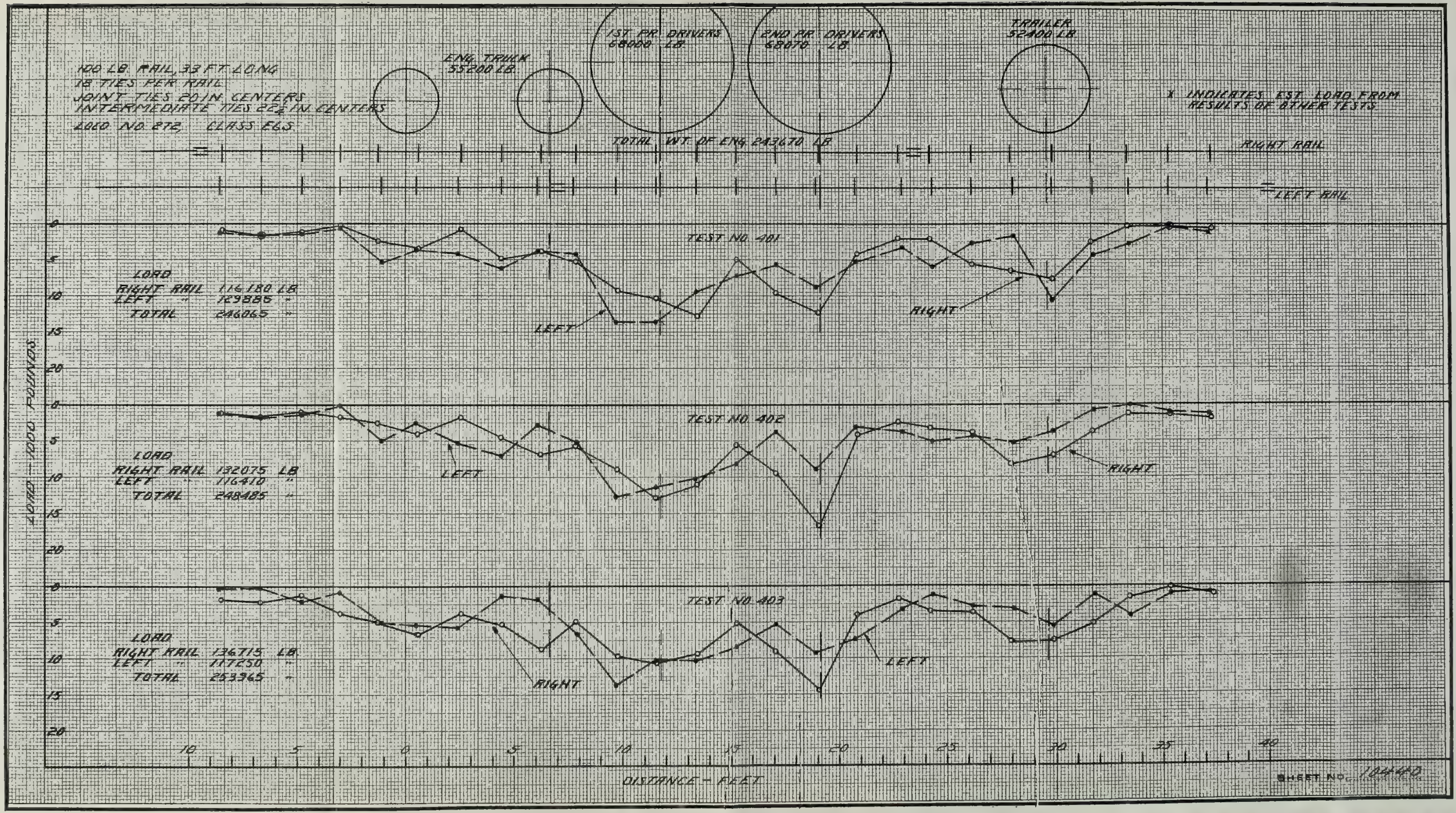

Distribution of Load Over Ties

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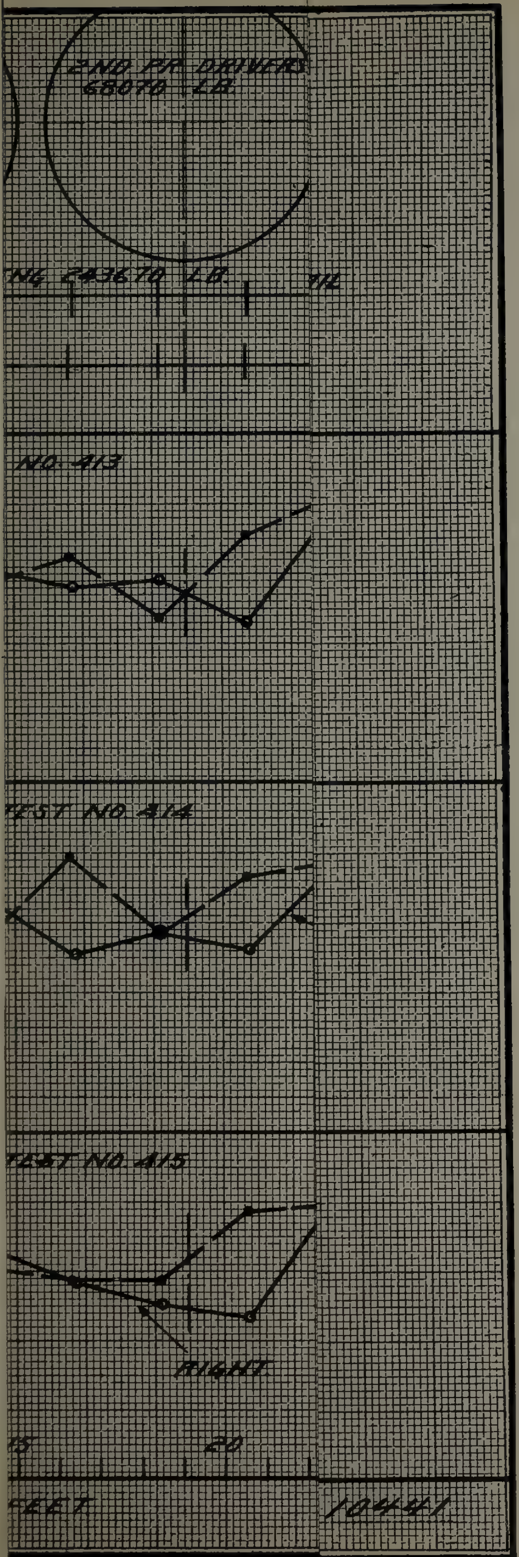
2ND PR. DRIVERS
68070 LB.
NG 243670 LB.
412
NO. 413
TEST NO. 414
TEST NO. 415
RIGHT
15
20
FEET
10441

LI[illegible]
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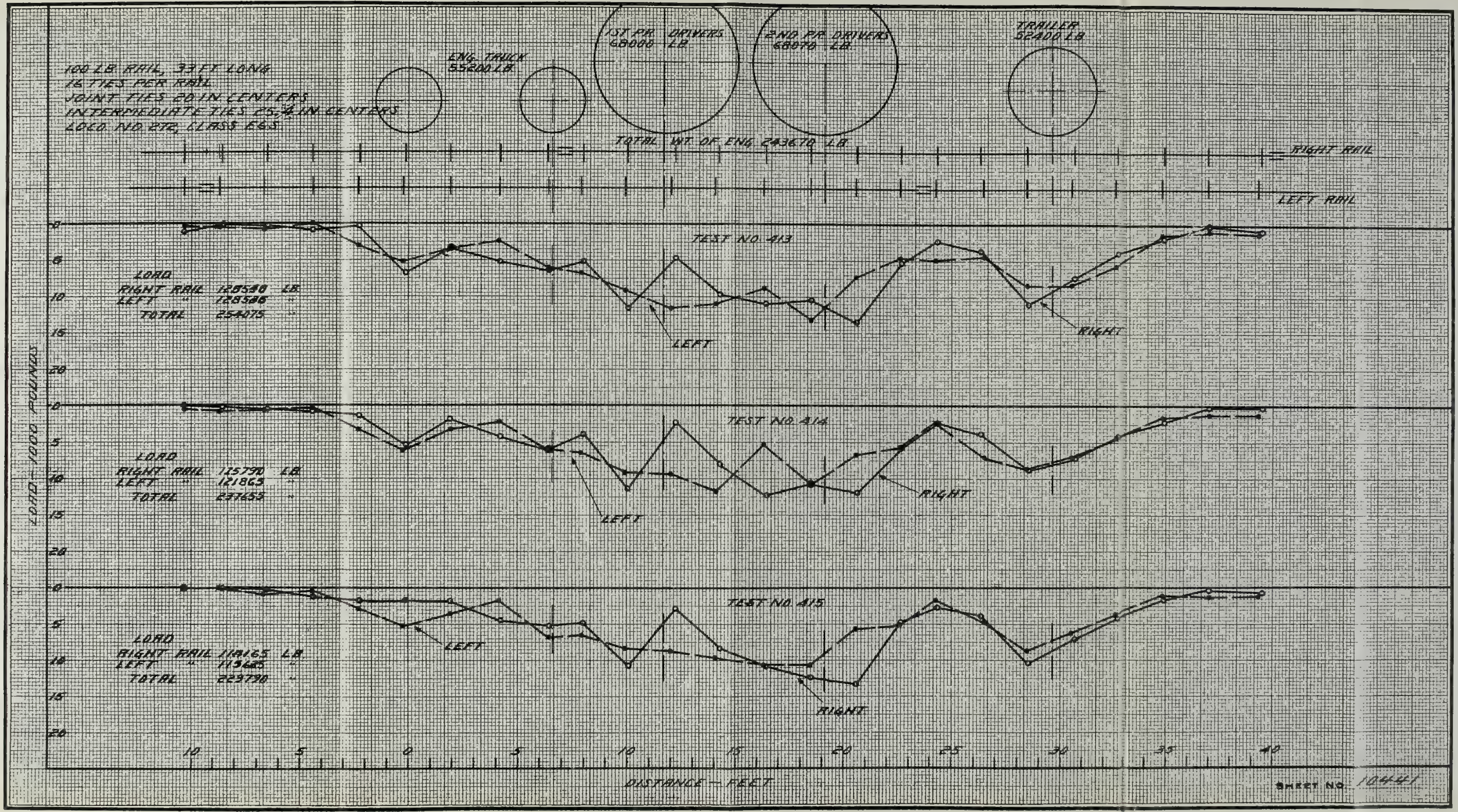

Distribution of Load Over Ties.

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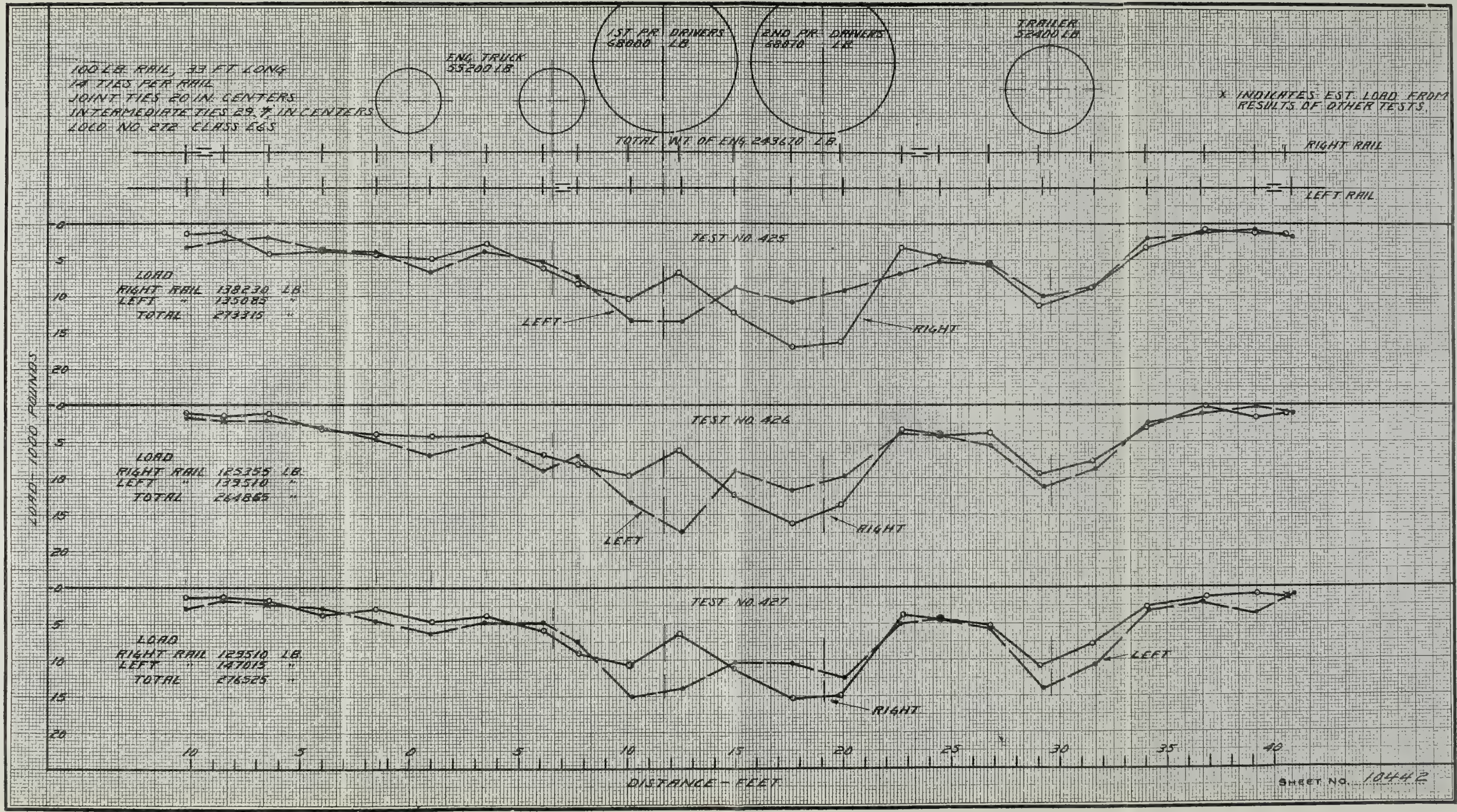
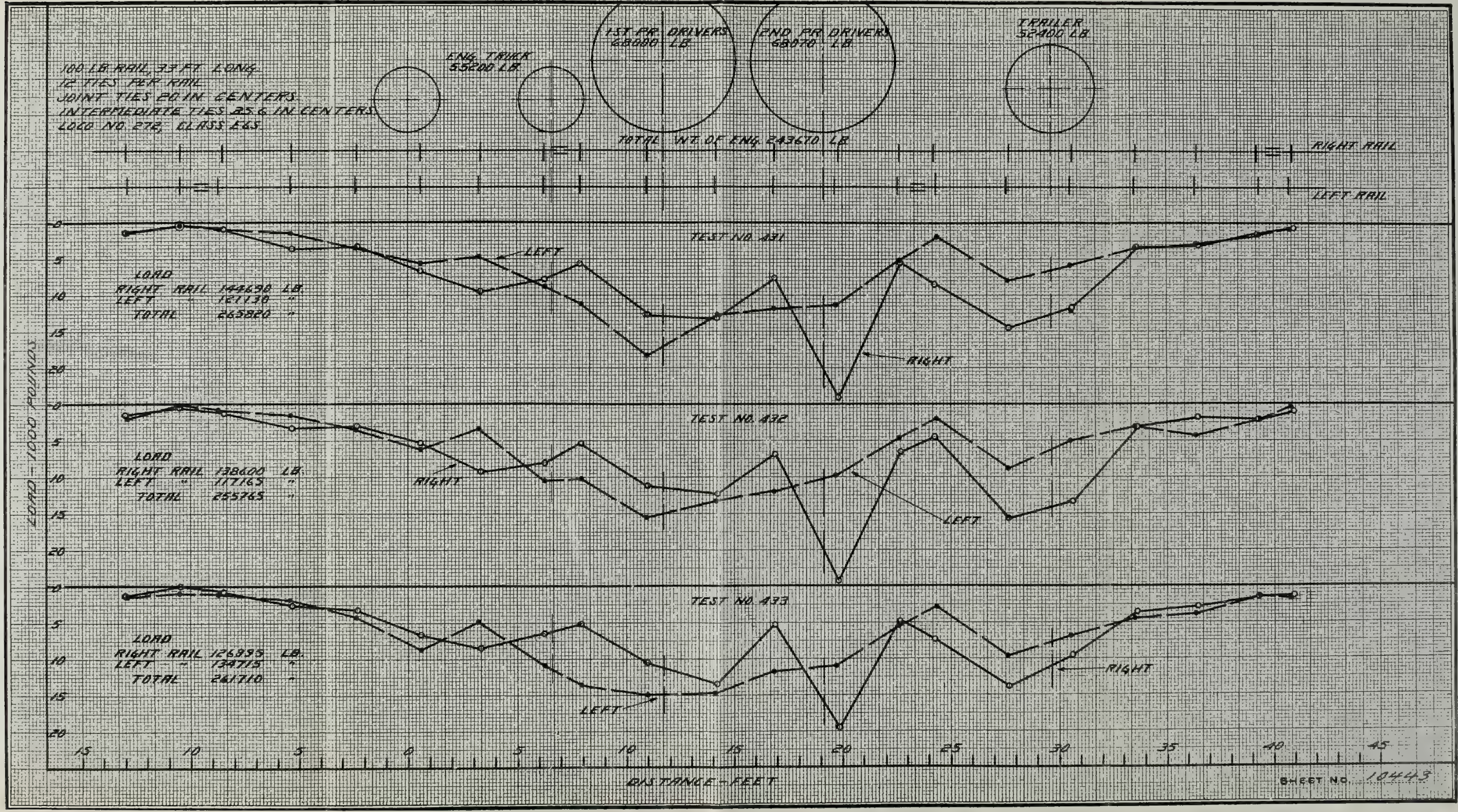


Distribution of Load Over Ties.


100 LB. RAIL, 33 FT. LONG.
12 TIES PER RAIL
JOINT TIES 20 IN. CENTERS.
INTERMEDIATE TIES 25.6 IN. CENTERS.
LOCO. NO. 272, CLASS E6S.
ENG. TRUCK 55200 LB.
1ST PR. DRIVERS 68000 LB.
2ND PR. DRIVERS 68070 LB.
TRAILER 52400 LB.
TOTAL WT. OF ENG. 243670 LB.
RIGHT RAIL
LEFT RAIL
TEST NO. 431
LEFT
RIGHT
LOAD
RIGHT RAIL 144690 LB.
LEFT " 121130 "
TOTAL 265820 "
TEST NO. 432
LOAD
RIGHT RAIL 138600 LB.
LEFT " 117165 "
TOTAL 255765 "
RIGHT
LEFT
TEST NO. 433
LOAD
RIGHT RAIL 126895 LB.
LEFT " 134715 "
TOTAL 261710 "
LEFT
RIGHT
LOAD - 1000 POUNDS
0
5
10
15
20
15 10 5 0 5 10 15 20 25 30 35 40 45
DISTANCE - FEET
SHEET NO. 10443

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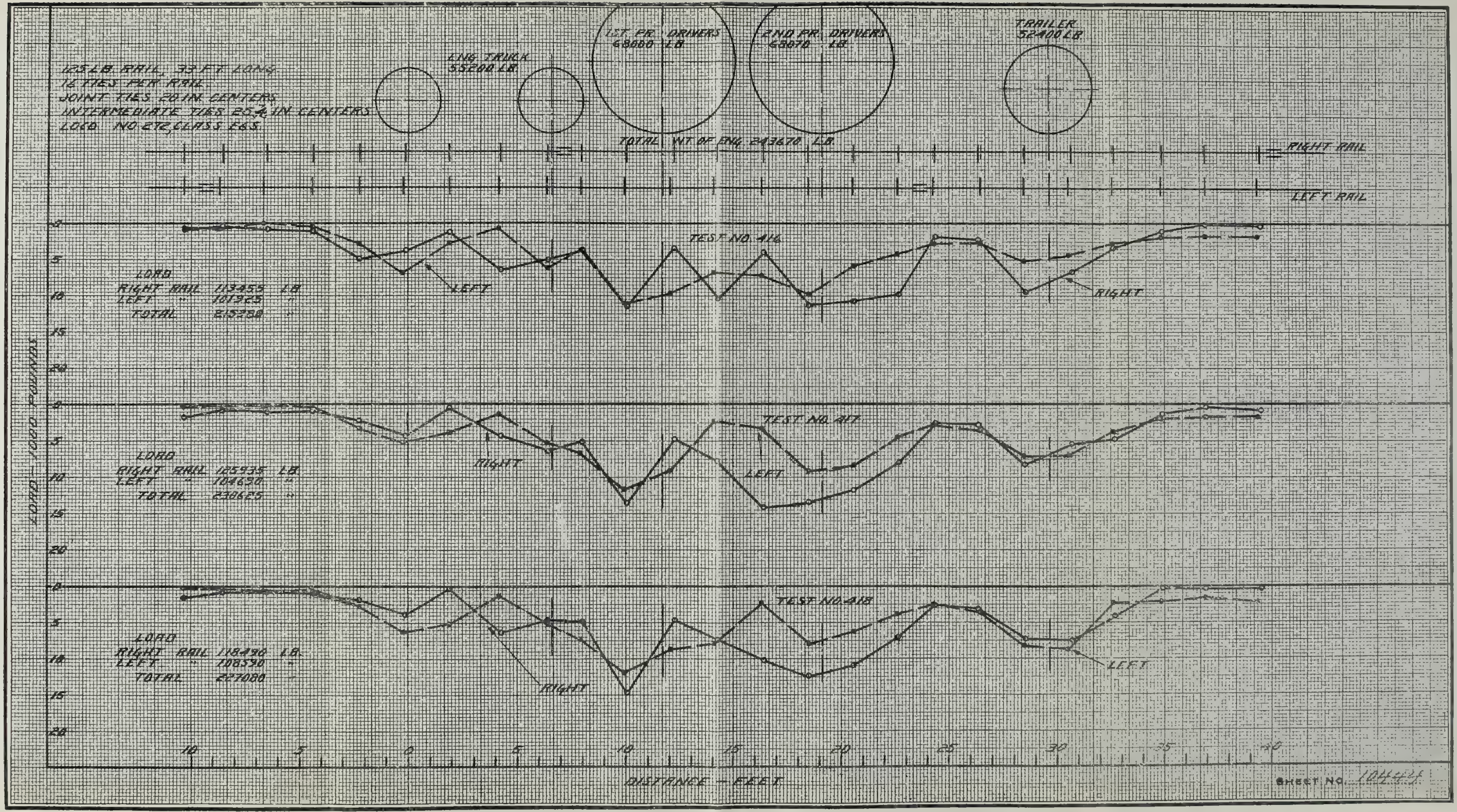

Distribution of Load Over Ties

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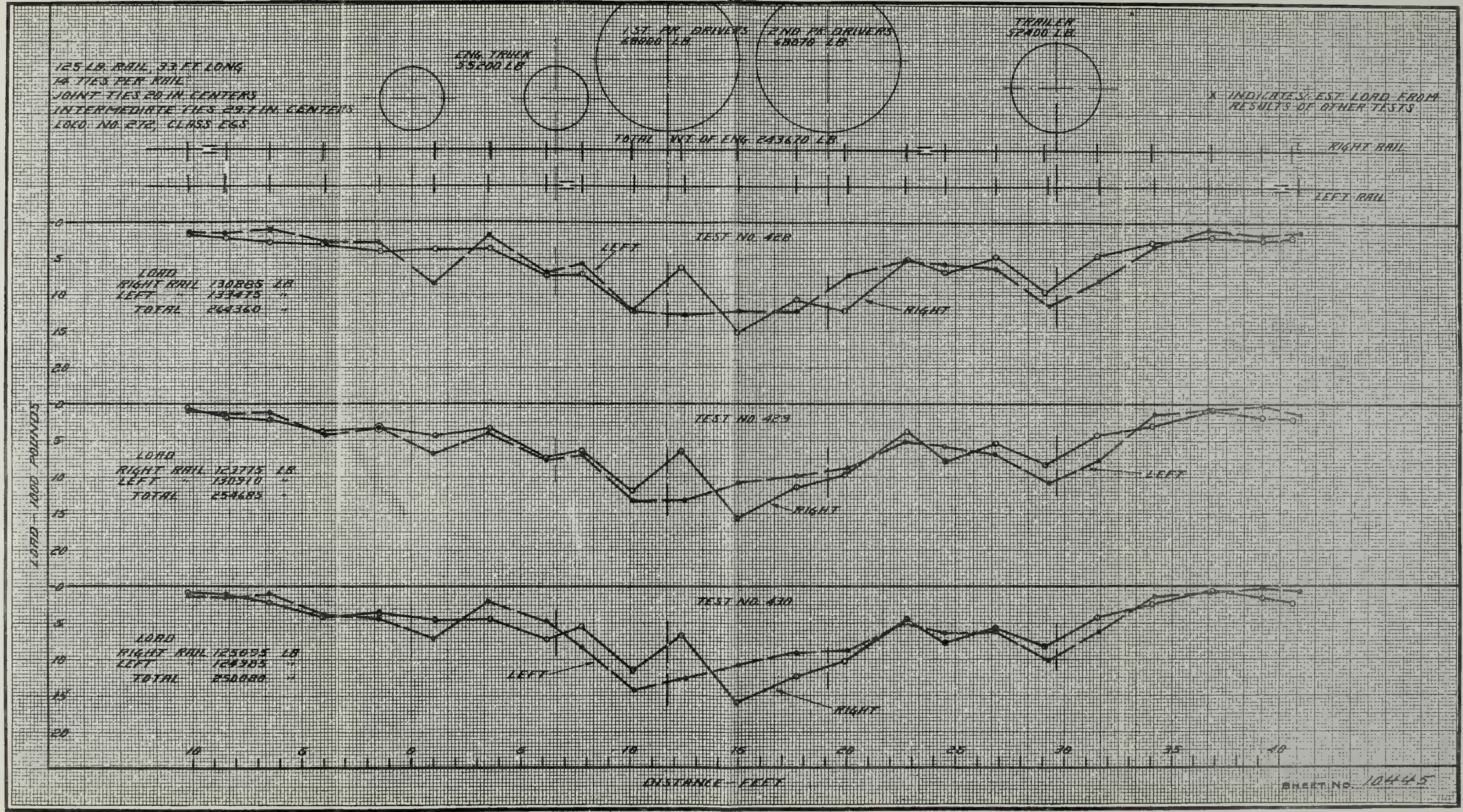

Distribution of Load Over Ties.

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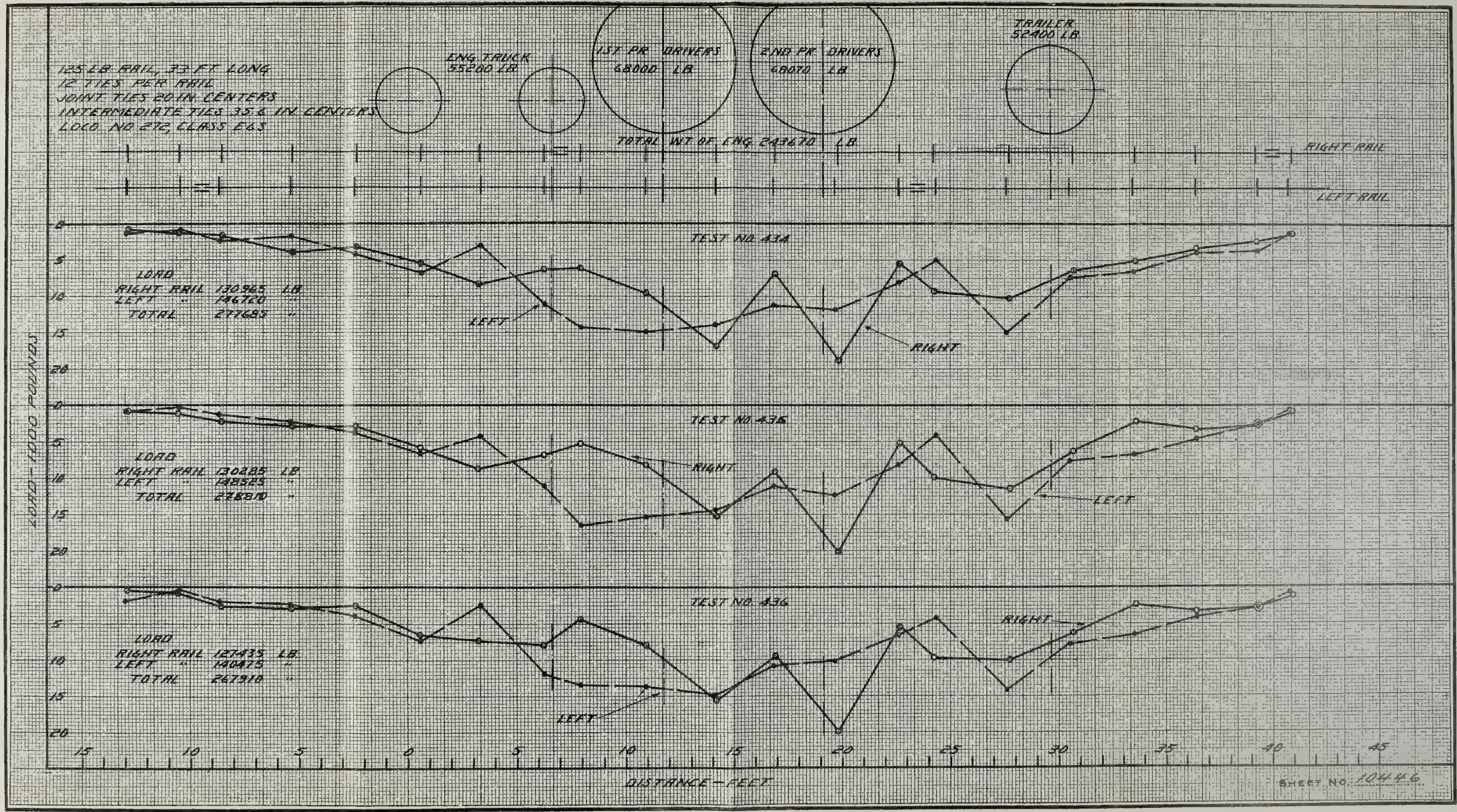

Distribution of Load Over Ties.

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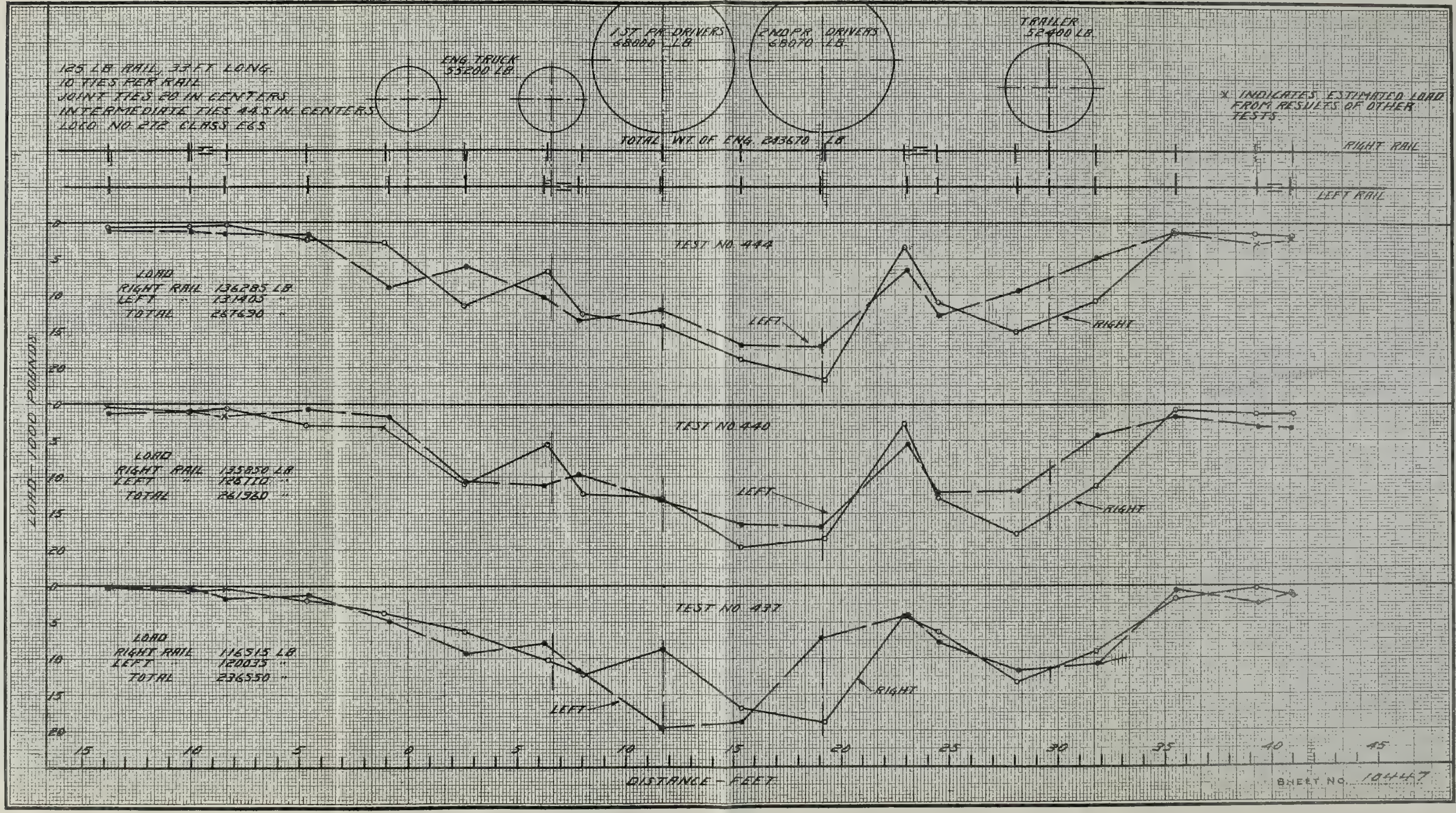

Distribution of Load Over Ties.

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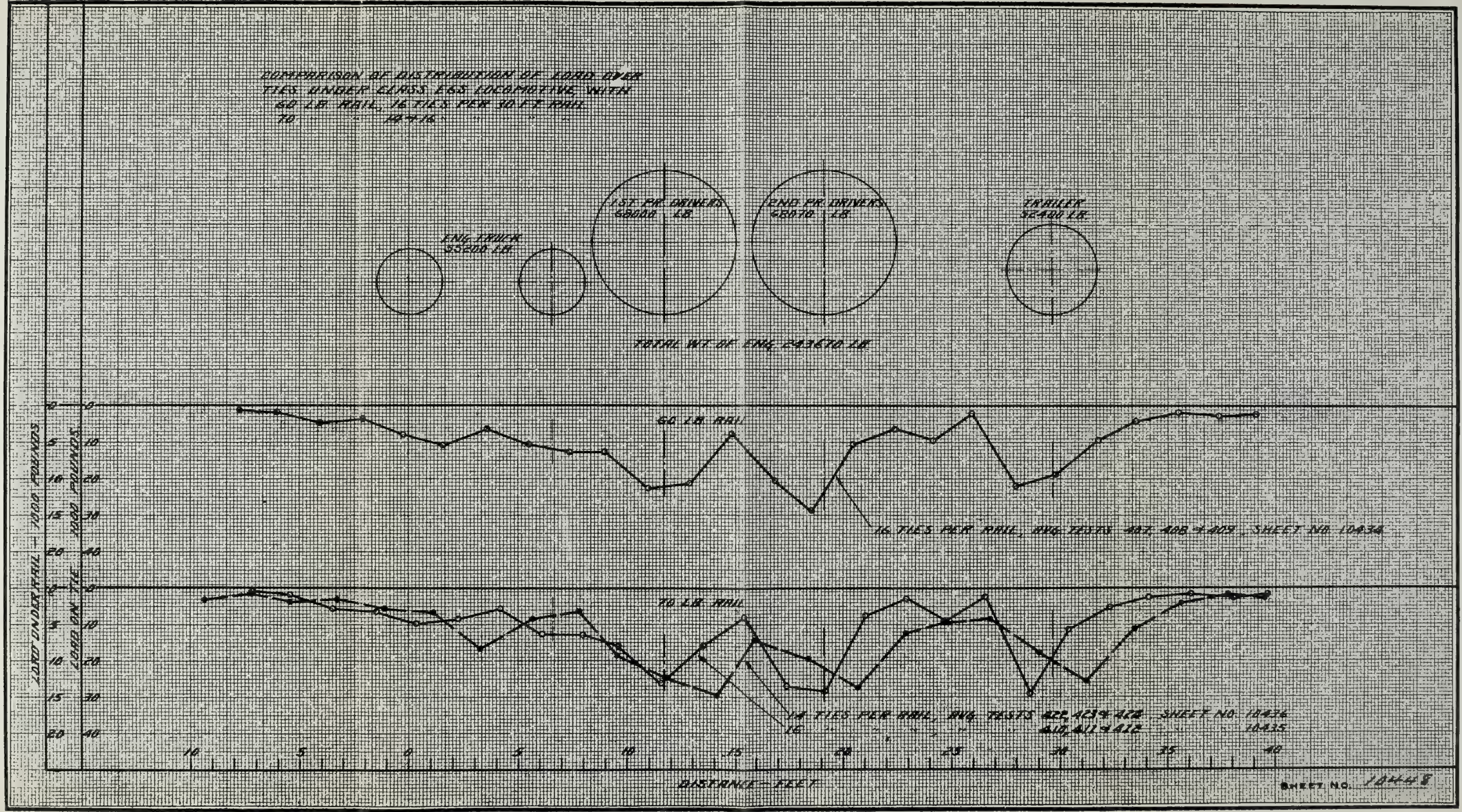

Distribution of Load Over Ties.

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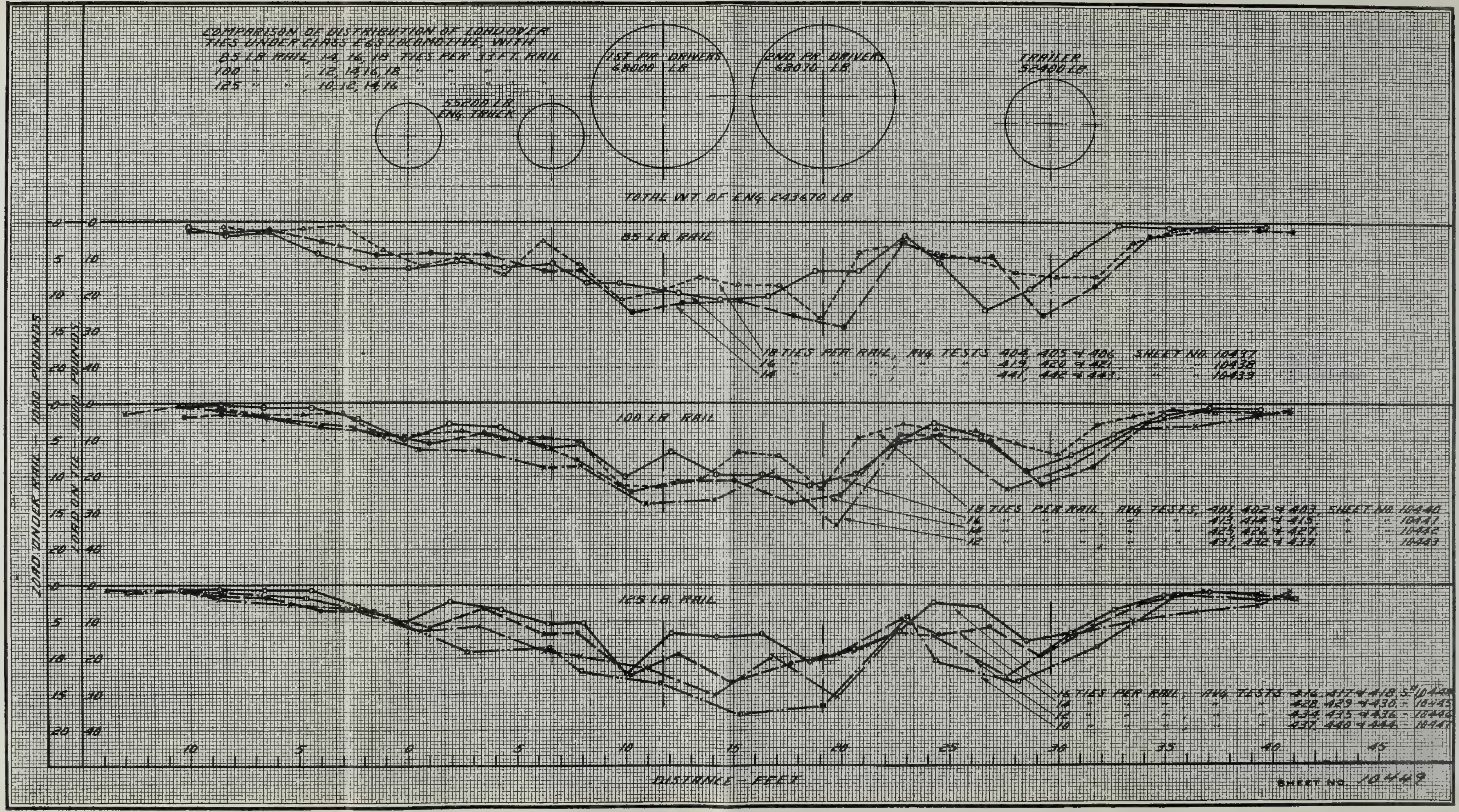

Distribution of Load Over Ties.

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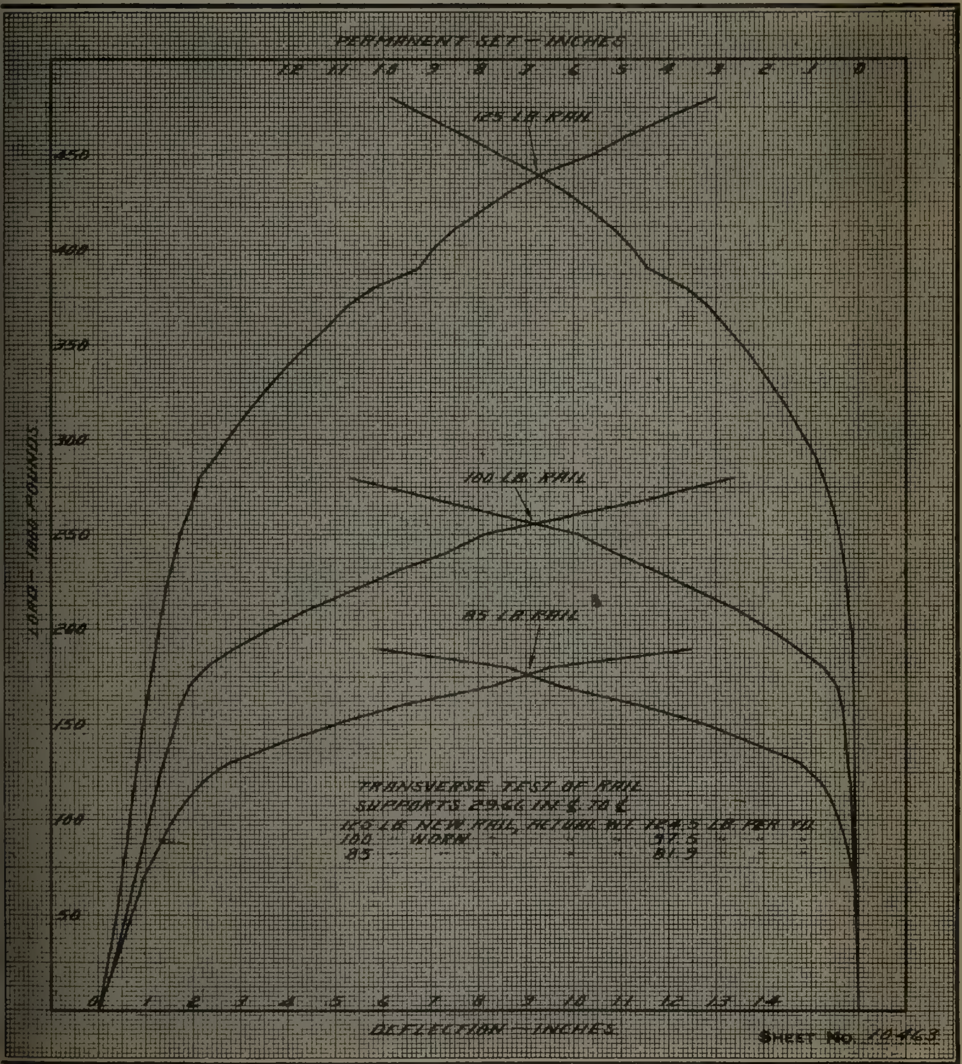
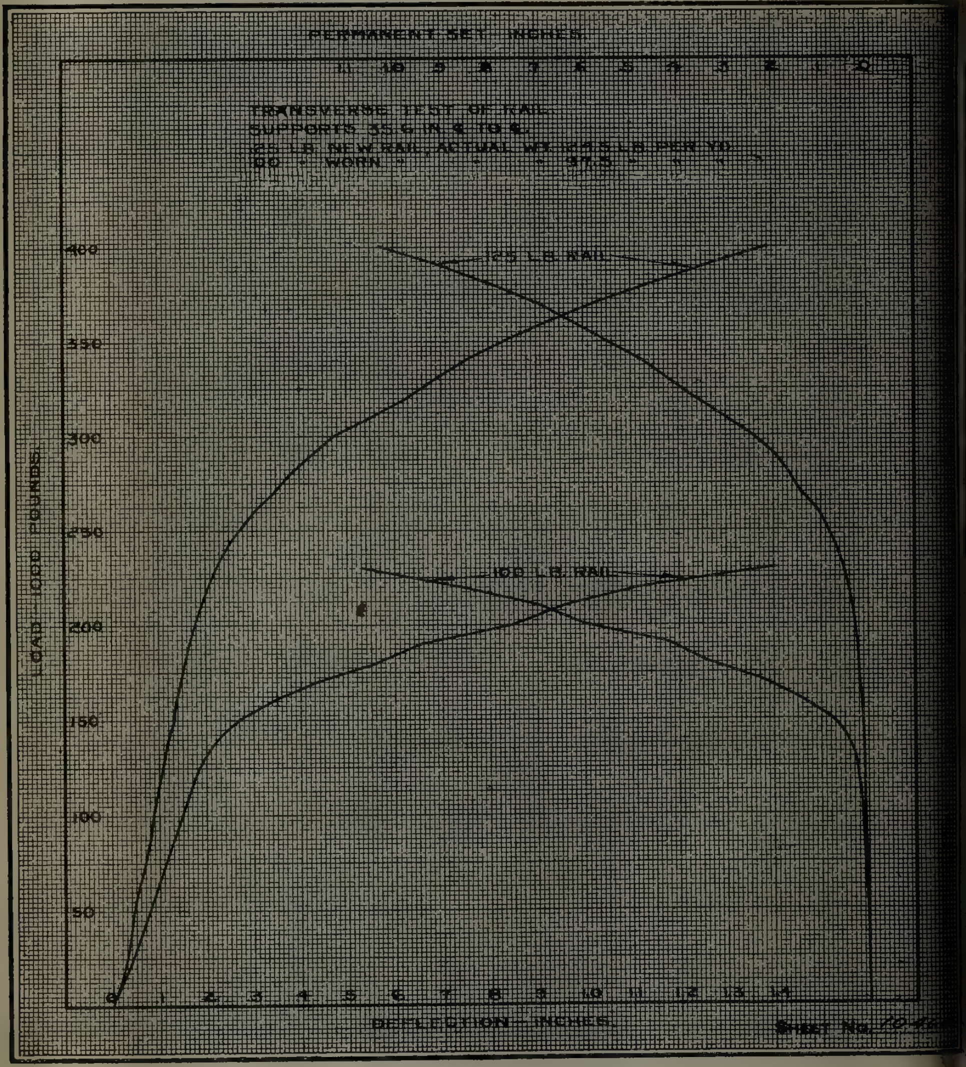
Report No. 15-102.
October 22, 1915.



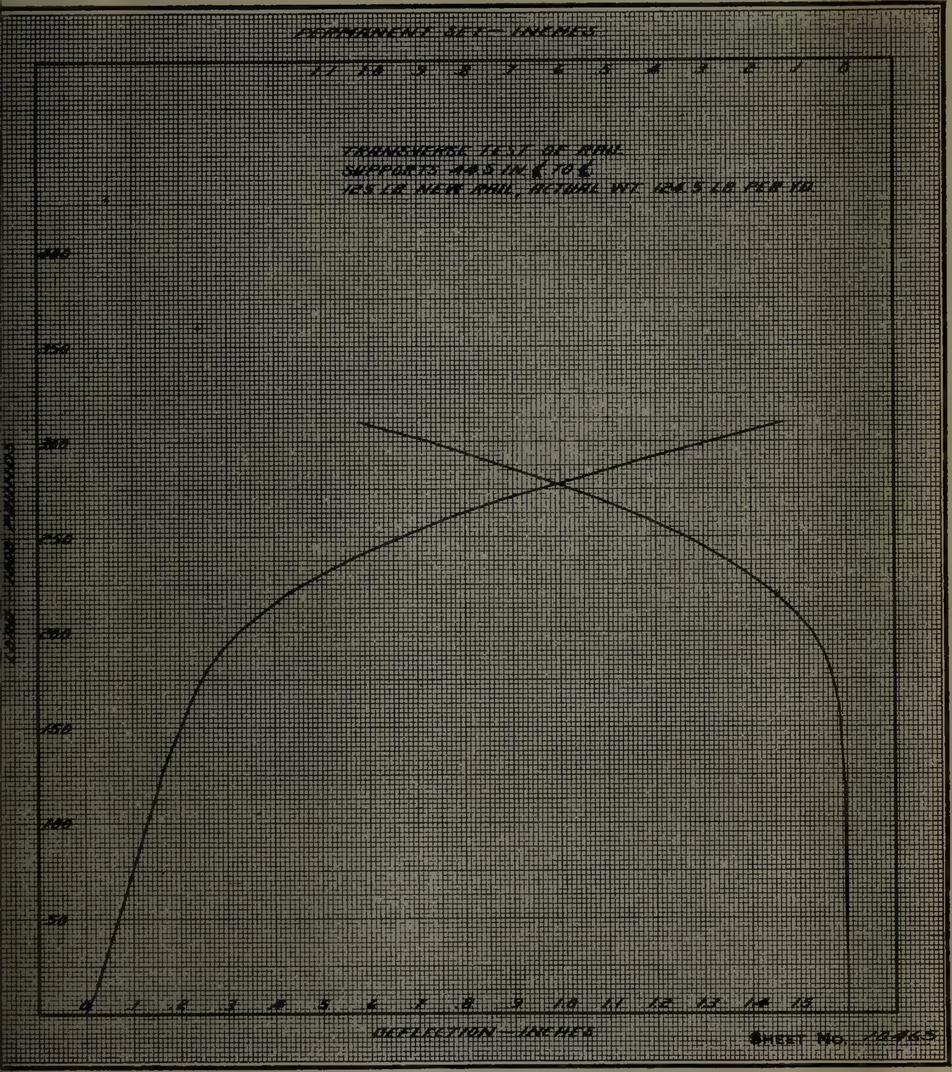
Distribution of Load Over Ties.

Report No. 15-10
October 22, 191



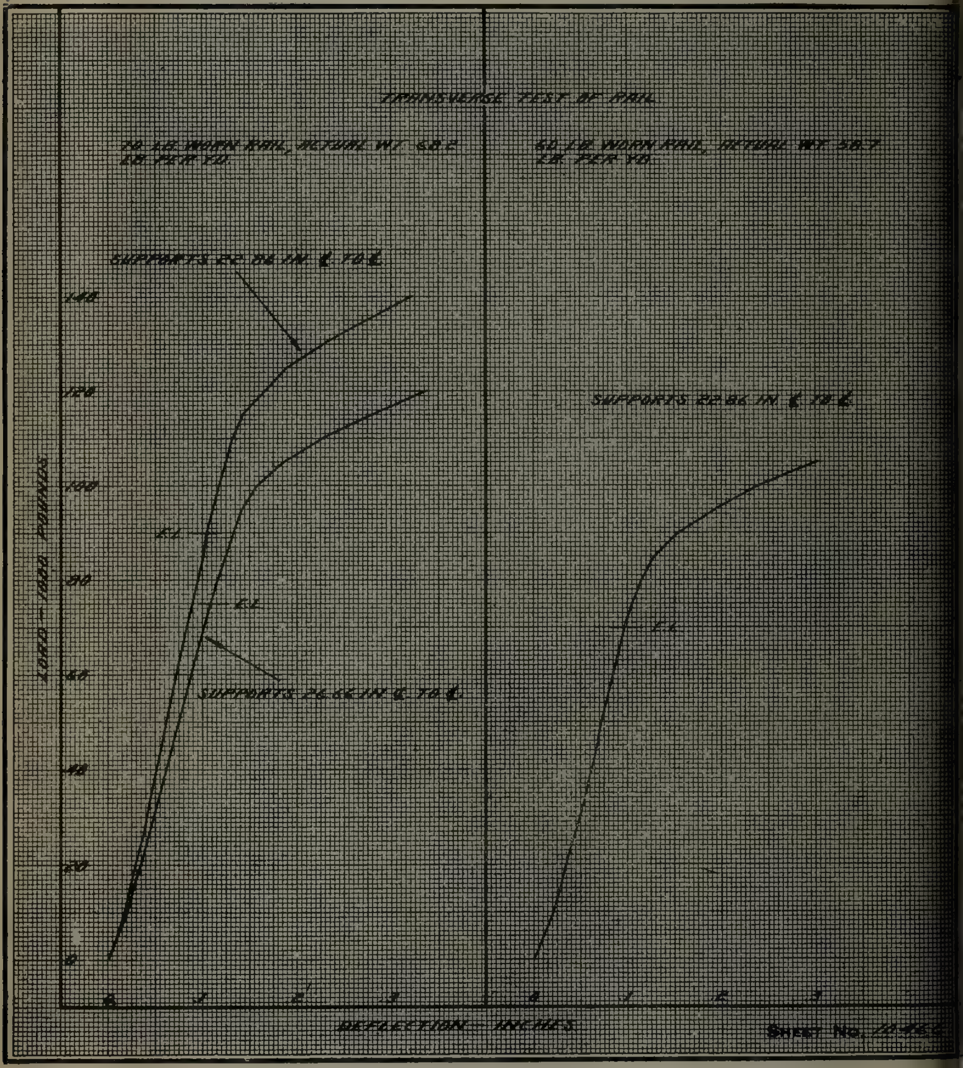
Distribution of Load Over Ties.

Report No. 15-102.
October 22, 1915.



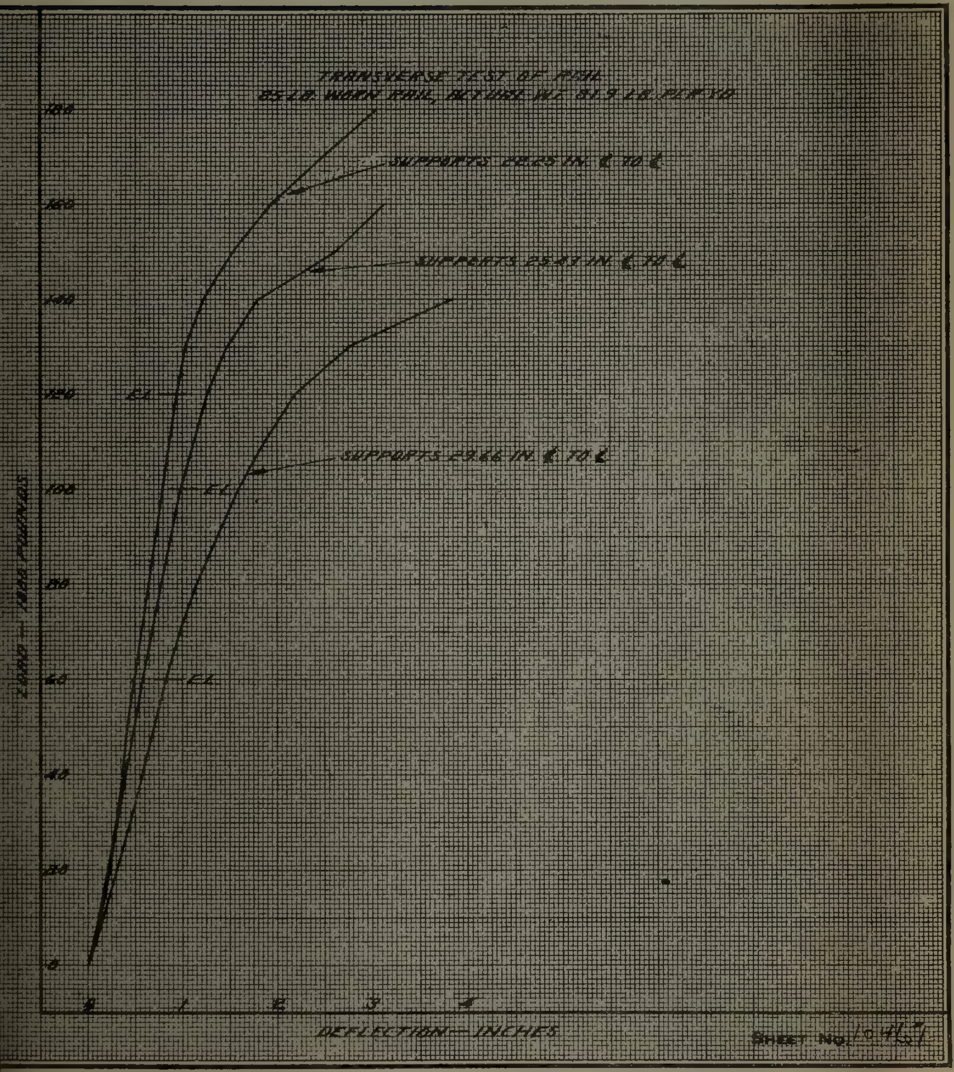
Distribution of Load Over Ties.

Report No. 15-10
October 22, 191



DISTRIBUTION OF LOAD OVER TIES.

Report No. 15-102.
October 22, 1915.



Distribution of Load Over Ties.

TRANSVERSE TEST OF RAIL.

COMPARISON OF ELASTIC LIMIT AND ULTIMATE STRENGTH OF DIFFERENT WEIGHTS OF RAIL WITH VARIOUS SPACINGS BETWEEN SUPPORTS.

Wt. of rail, Lbs. per Yd.		Distance between supports inches	Elastic Limit pounds	Ultimate Strength pounds	Comparison %	
Nominal	Actual				Elastic Limit	Ultimate Strength
100	97.5	22.25	180000	515860	100	100
"	"	25.43	140000	412140	78	80
"	"	29.66	130000	287500	72	56
"	"	35.60	120000	248280	67	48
125	124.5	25.43	210000	696080	117	135
"	"	29.66	180000	574860	100	111
"	"	35.60	140000	491720	78	95
"	"	44.50	120000	375420	67	73
85	81.9	22.25	120000	388140	67	75
"	"	25.43	100000	306980	56	60
"	"	29.66	60000	241700	33	47
70	68.2	22.86	90000	250080	50	49
"	"	26.66	75000	202040	42	39
60	58.7	22.86	70000	166480	39	32

NOTE: 125 lb. rail new; other rail previously in service.

DEFORMATION OF CROSS-TIES UNDER LOAD ON RAILS.

March 30, 1915.

W. G. C.:

In compliance with your directions of last September, we have made a test to determine the deformation of a cross-tie under load. Four locations were selected, as follows:

No. 1—Inward passenger track near 37th St., West Philadelphia, representing first-class track on stone ballast. White Oak ties.

No. 2—Outward passenger track No. 3 at "GC" Block Station (near Powelton Ave.); also on stone ballast, but with less solid roadbed. White Oak tie.

No. 3—Main freight track No. 17, near 37th Street. Cinder ballast, well-maintained track, under heavy traffic. White Oak tie.

No. 4—Schuylkill River Branch, eastward freight track, west of 30th Street. Cinder ballast. Track not so well maintained, but with much lighter traffic. Yellow Pine tie.

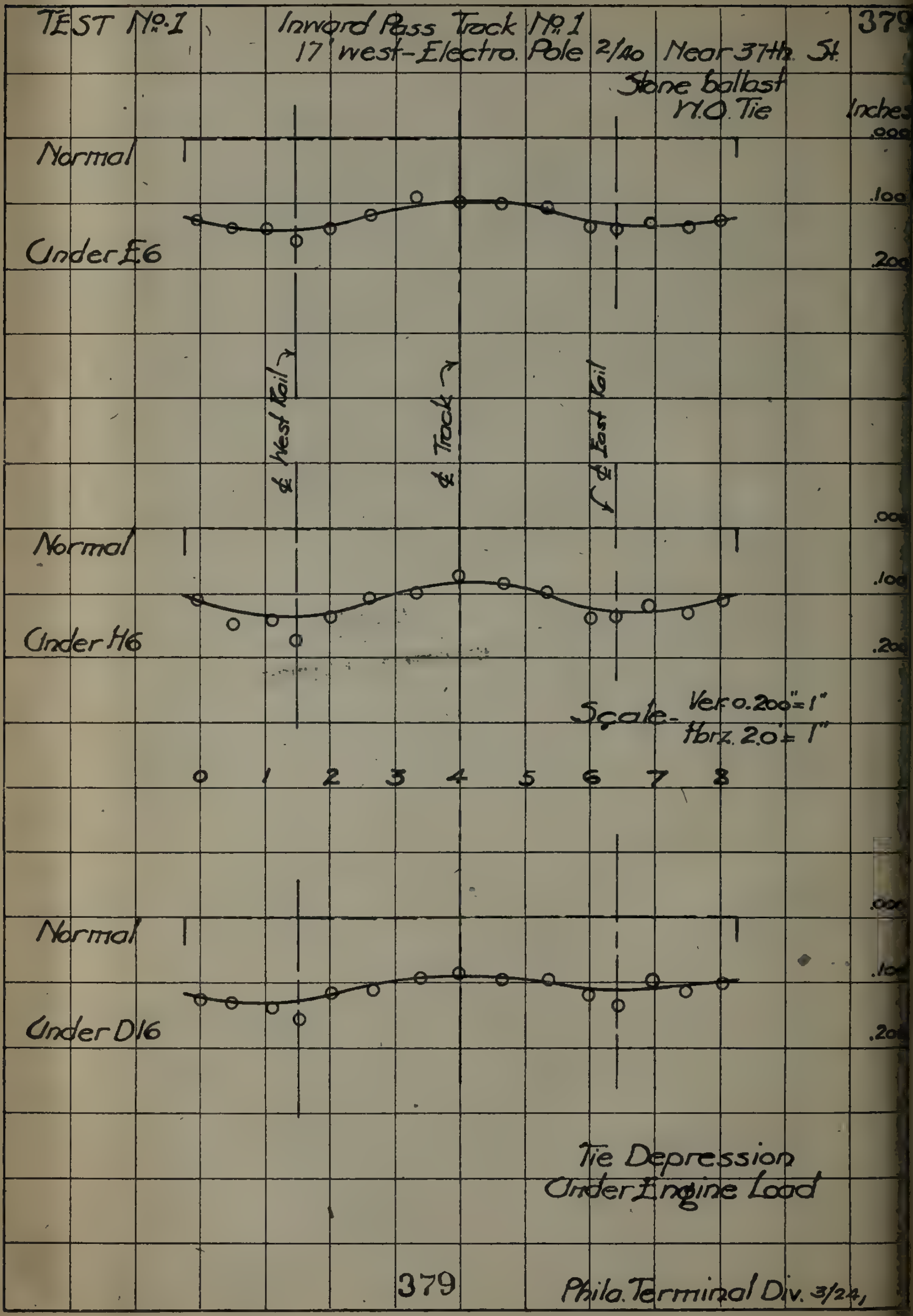
Thirteen nails were driven in the tie whose deformation was to be measured; heavy stakes were driven in line with the tie, one on each side of the track; a steel straight-edge (plan attached) was secured to the tops of the stakes, and the distance between the lower edge of the straight-edge and the tops of the nails was measured with a micrometer scale. A locomotive was then placed over the tie with the wheels bearing the maximum load as close to the tie as practicable, the straight-edge placed in same position as before and the measurements repeated under the locomotive.

Three locomotives were used in this test at each of the four locations, viz., E-6, H-6 and D-16.

Readings were also taken from top of rail, but as the results showed that these readings did not truly indicate the depression of the tie (owing to space between the rail and tie-plate or tie-plate and tie, or both, when not loaded) they were disregarded in plotting the curves.

As the middle of the tie is depressed more under load than the ends in every case except the highest type of roadbed, it would seem that a length of 8 ft. 6 in. is too great for any but first-class passenger track.

J. C. C.


TEST No. 1
Inward Pass Track No. 1
17' west-Electro. Pole 2/40 Near 37th St.
Stone ballast
W.O. Tie
379
Inches
.000
.100
.200
Normal
Under E6
℄ West Rail
℄ Track
℄ East Rail
.000
.100
.200
Normal
Under H6
Scale- Ver. 0.200" = 1"
Horz. 2.0' = 1"
0
1
2
3
4
5
6
7
8
.000
.100
.200
Normal
Under D16
Tie Depression
Under Engine Load
379
Phila. Terminal Div. 3/24

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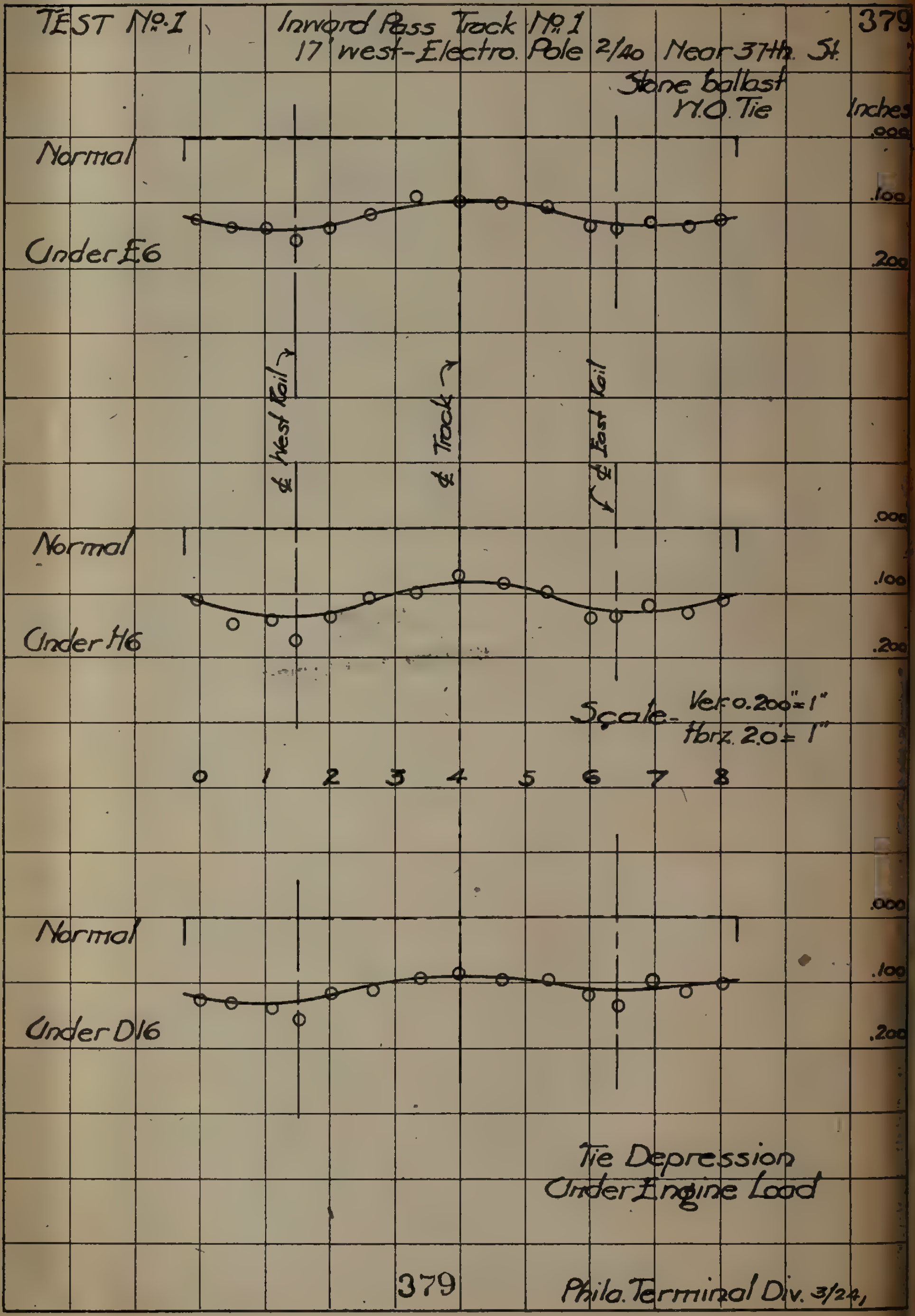
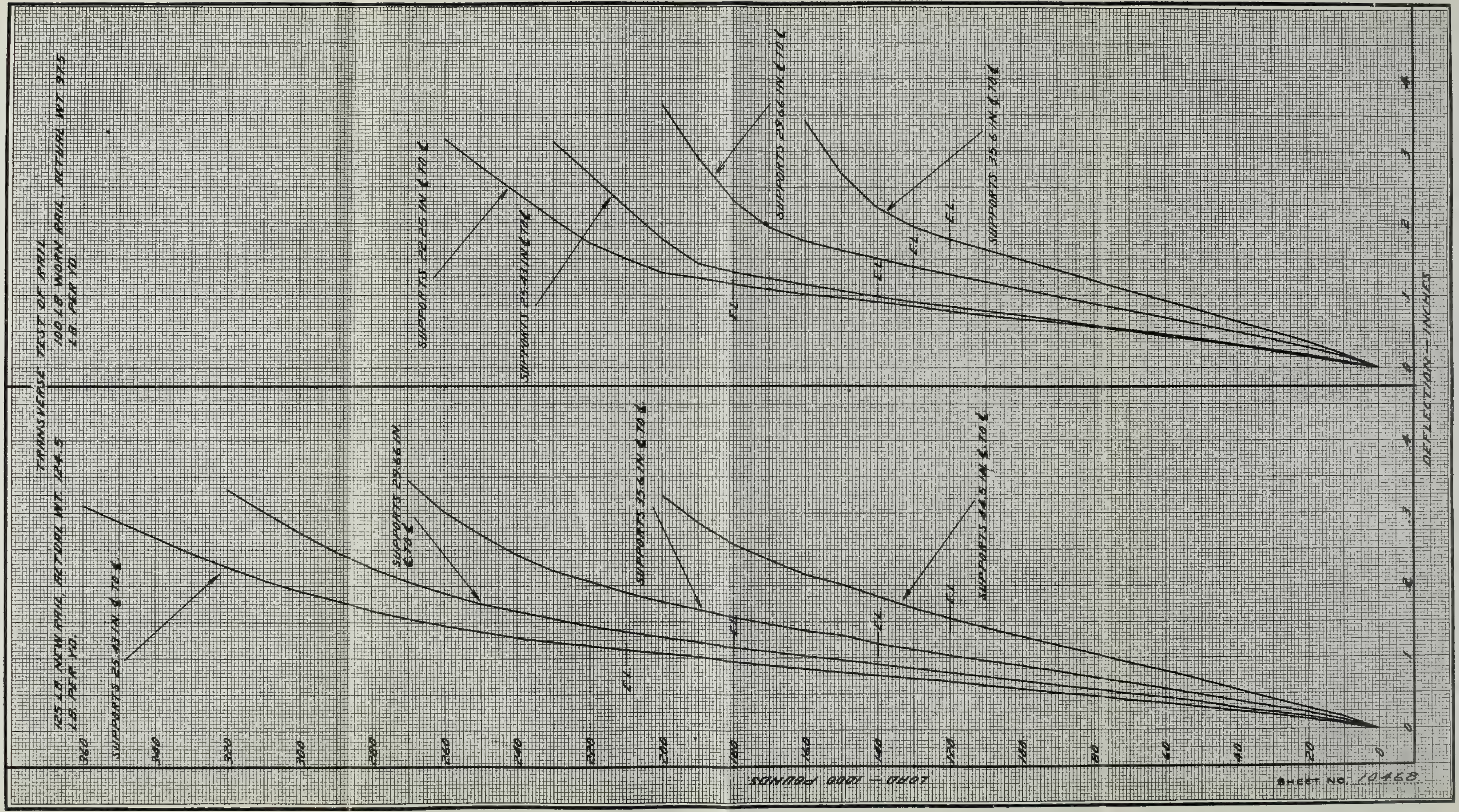
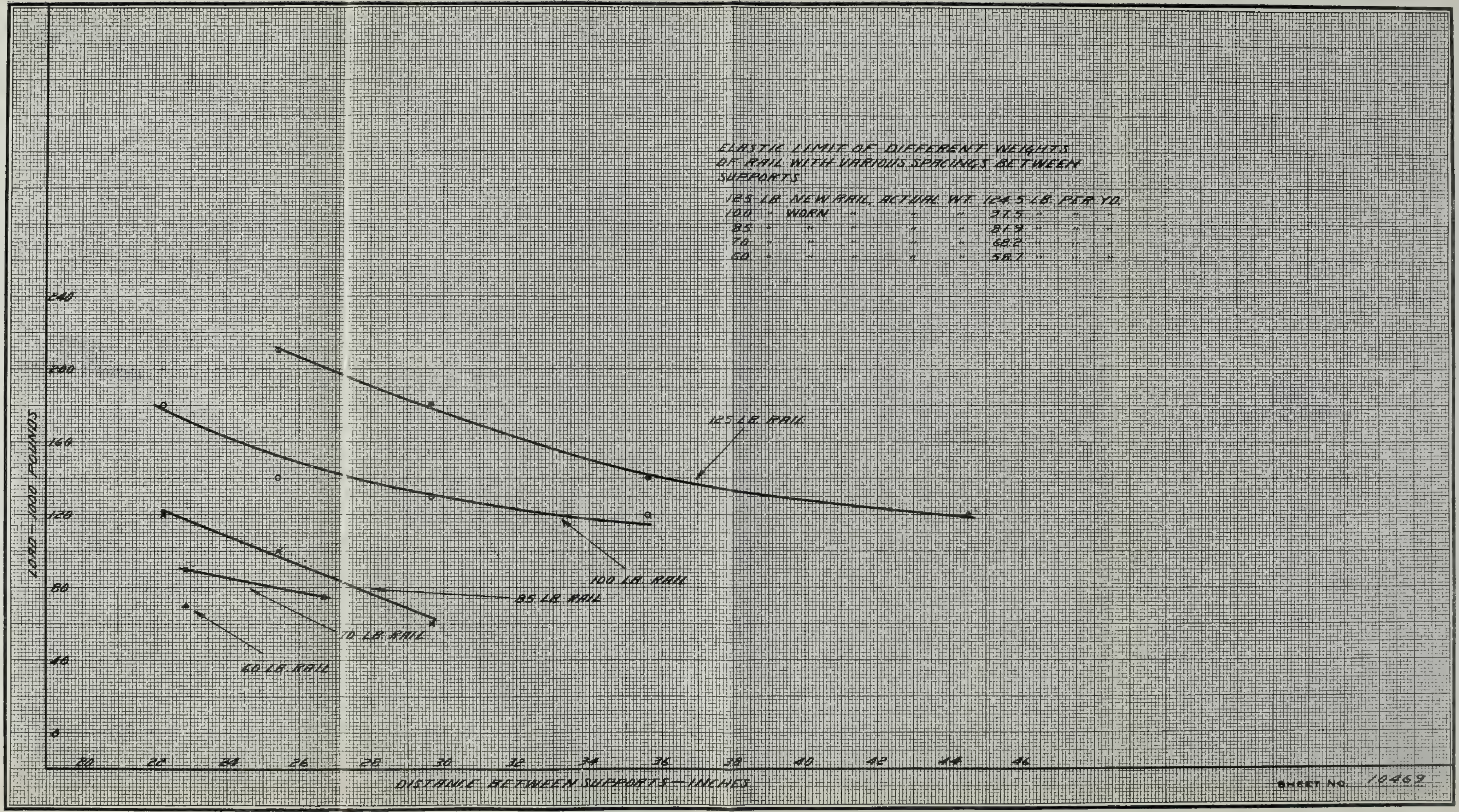
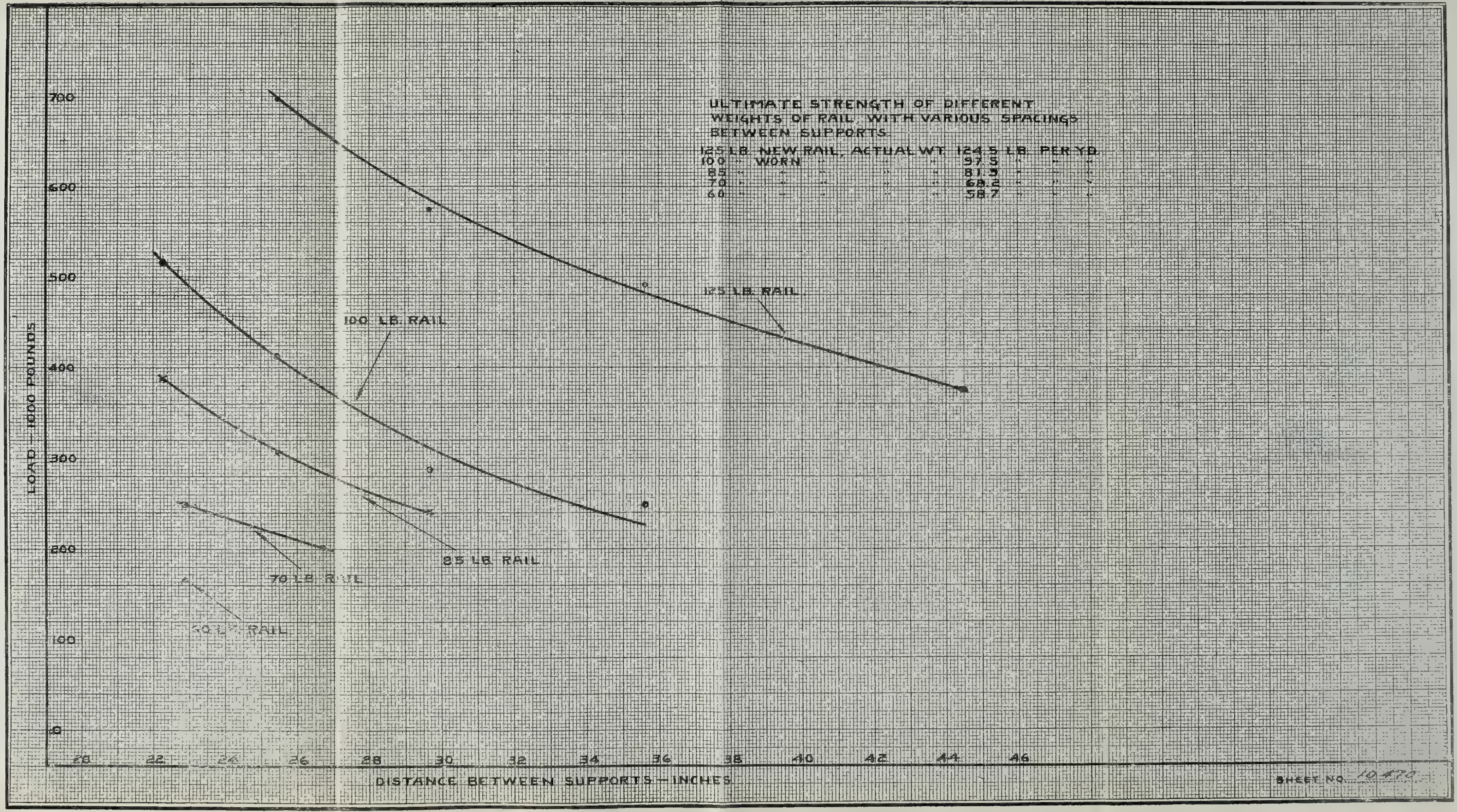

TEST No. 1
Inward Pass Track No. 1
17' west-Electro. Pole 2/40 Near 37th. St.
Stone ballast
W.O. Tie
379
Inches
.000
.100
.200
Normal
Under E6
℄ West Rail
℄ Track
℄ East Rail
Normal
Under H6
Scale- Vert. 0.200" = 1"
Horz. 2.0' = 1"
0 1 2 3 4 5 6 7 8
Normal
Under D16
Tie Depression
Under Engine Load
379
Phila. Terminal Div. 3/24,



Distribution of Load Over Ties


ELASTIC LIMIT OF DIFFERENT WEIGHTS
OF RAIL WITH VARIOUS SPACINGS BETWEEN
SUPPORTS
125 LB. NEW RAIL, ACTUAL WT. 124.5 LB. PER YD.
100 " WORN " " " 97.5 " " "
85 " " " " " 81.9 " " "
70 " " " " " 68.2 " " "
60 " " " " " 58.7 " " "
125 LB. RAIL
100 LB. RAIL
85 LB. RAIL
70 LB. RAIL
60 LB. RAIL
LOAD—1000 POUNDS
240
200
160
120
80
40
0
20
22
24
26
28
30
32
34
36
38
40
42
44
46
DISTANCE BETWEEN SUPPORTS—INCHES
SHEET NO. 10469



Distribution of Load Over Ties

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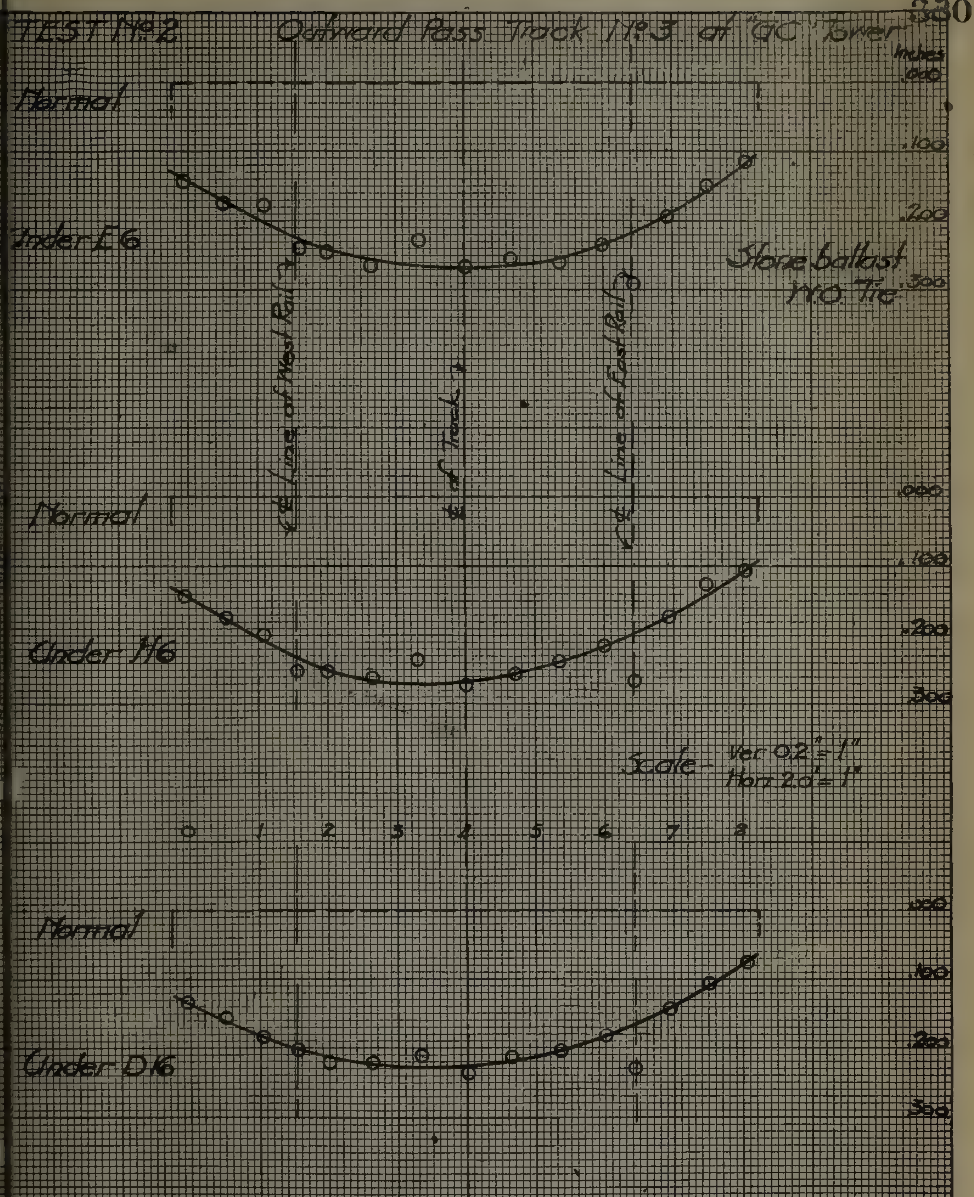
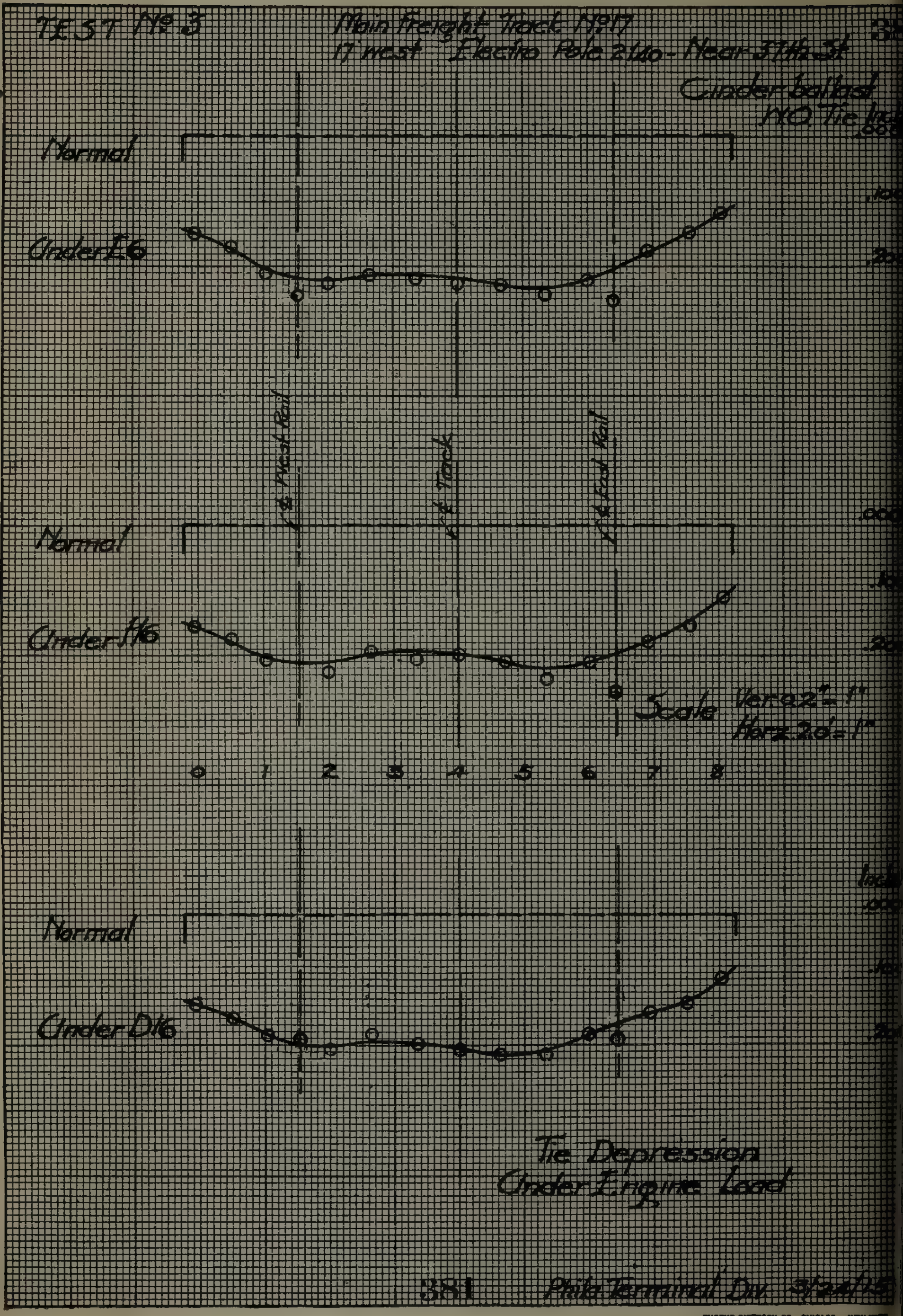
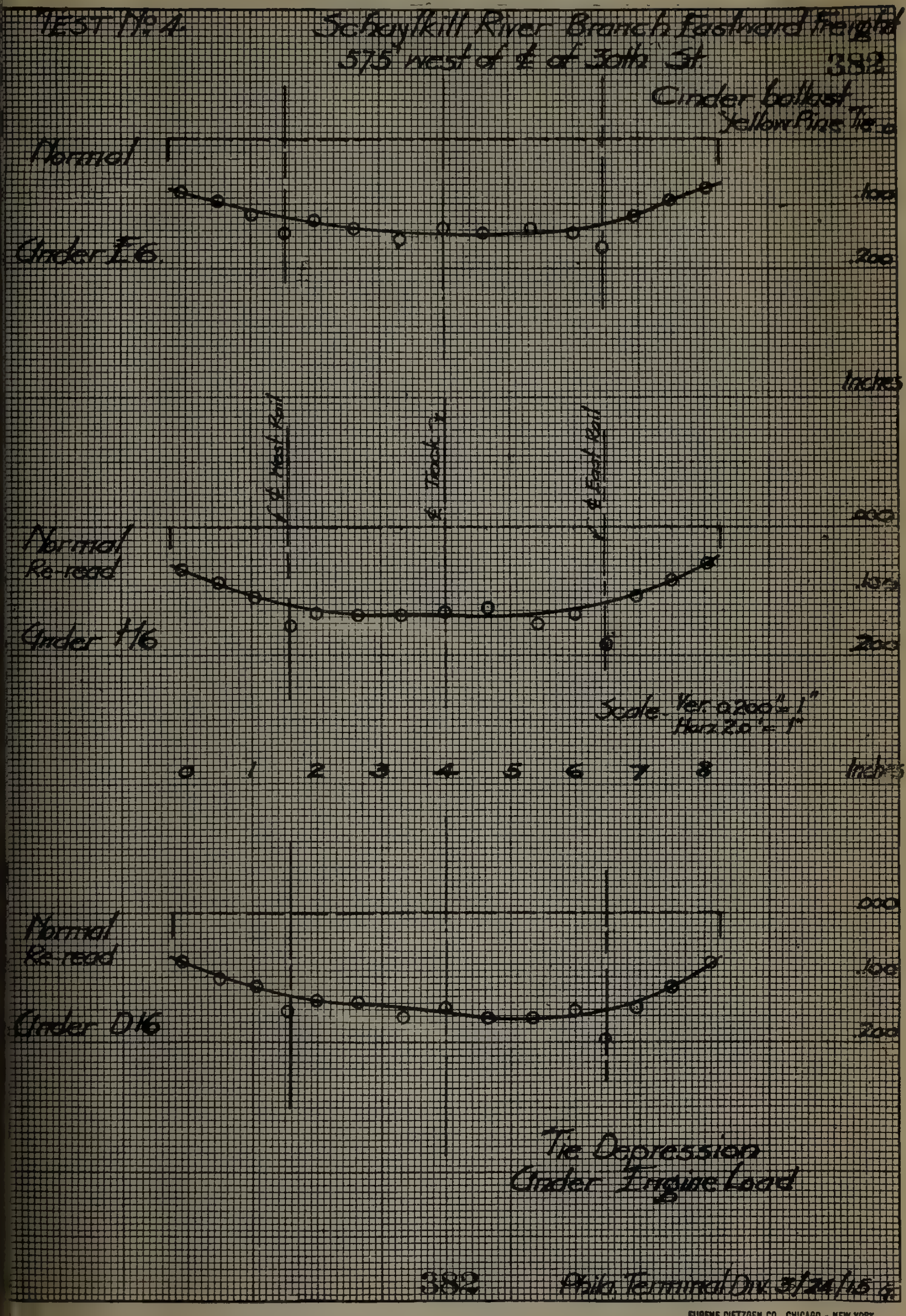


EUGENE DIETZGEN CO., CHICAGO - NEW YORK.


TEST No 3
Main Freight Track No 17
17' west Electric Pole 2140 - Near 31th St
Cinder ballast
NO Tie
Normal
Under E6
Normal
Under F16
Normal
Under D16
℄ West Rail
℄ Track
℄ East Rail
Scale Vert .02" = 1"
Horz 2.0' = 1"
0
1
2
3
4
5
6
7
8
.000
.100
.200
Inches
Tie Depression
Under Engine Load
381
Phila Terminal Div. 3/24/15
EUGENE DIETZGEN CO., CHICAGO - NEW YORK.


Test No. 4
Schuylkill River Branch Eastward Freight
575' west of ℄ of 30th St
382
Cinder ballast
Yellow Pine Ties
Normal
Under E6.
.100
.200
Inches
℄ West Rail
℄ Track
℄ East Rail
Normal
Re-read
Under H6
.000
.100
.200
Scale - Ver. 0.200" = 1"
Horz. 2.0' = 1"
0
1
2
3
4
5
6
7
8
Inches
Normal
Re-read
Under D16
.000
.100
.200
Tie Depression
Under Engine Load
382
Phila. Terminal Div. 3/24/15
EUGENE DIETZGEN CO., CHICAGO - NEW YORK

A. B. C.:

As per your memorandum of March 31st, we have repeated the tests to determine the deformation of a cross-tie under load, reported March 30, modifying the apparatus as per attached blueprint and making the tests with moving loads.

We attach blueprints showing the results of the repeat tests, and also for convenient comparison, blueprint of original tests.

Test No. 1—The dynamic test shows the same depression at the east end, somewhat less at the center, and nearly double the depression at the west end of the ties as compared with the static test.

The reason for this rather peculiar result is not obvious, but the theory that seems most plausible is that it is due to the elasticity of the tie. At the point where this test was made, the track was shifted some months ago so that about half of the tie is on old roadbed. This results in "center-bound" track, with the east end of the tie better supported than the west end.

In the static test, the tendency of the tie to resume its normal shape while under load (its elasticity) would partially offset the inequalities in support and in application of load, while in the dynamic test this force would not have time to operate.

Test No. 2—The deformation of the tie is about the same under the dynamic load as under the static, and the depression is about the same at the east end of the tie, but about 40 per cent. greater at the west end.

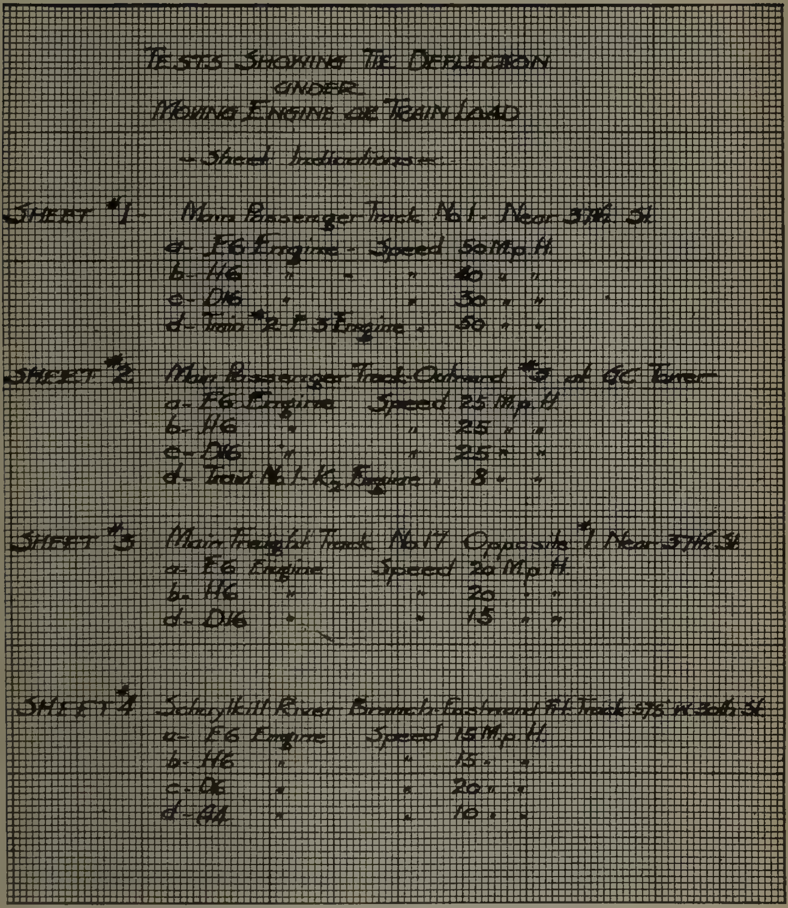
It will be noticed that the depression is slightly greater at the west end of the tie under the static load, indicating that the roadbed is more yielding under that side of the track. Probably this condition caused the locomotive to rock, thereby greatly increasing the dynamic load on the west side.

Test No. 3—In this test the depression was considerably increased under the east rail only; possibly for the reason suggested under Test 2.

Test No. 4—Train movements over this track are much less frequent than at the locations of the other tests and the cinder ballast is compacted around the ties so that there is very little movement of the track superstructure under trains. The depression of the tie is about the same under dynamic load as under static, being somewhat less at the middle of the tie, which may perhaps be explained by the theory stated under Test 1.

At 37th Street (Test No. 1) readings were taken after passage of Train No. 2, and at "GC" (Test No. 2) after Train No. 1. The results are the same as with unattached locomotives of similar weight.

April 28, 1915. J. C. C.



TESTS SHOWING TIE DEFLECTION
UNDER
MOVING ENGINE OR TRAIN LOAD

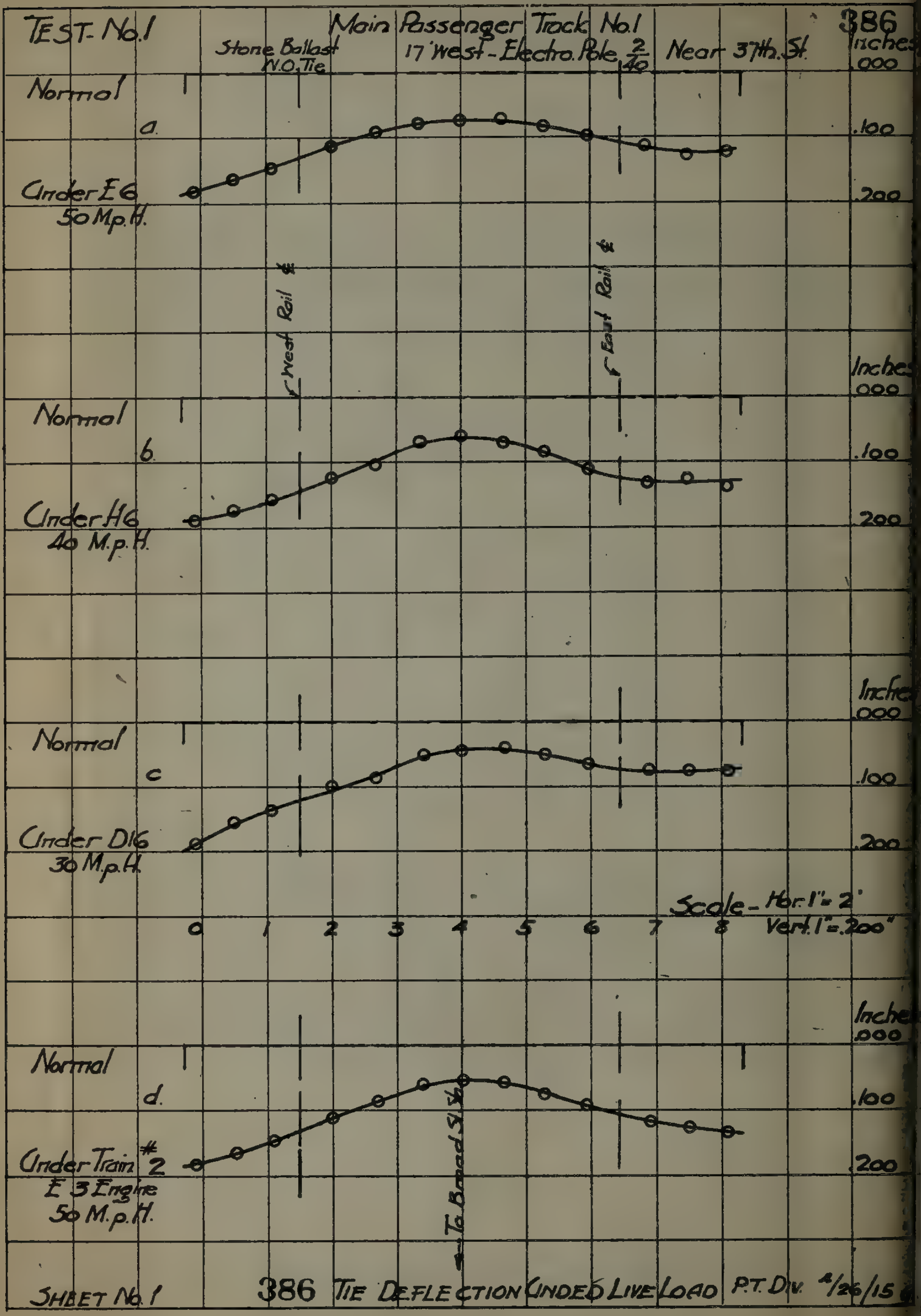
– Sheet Indications –

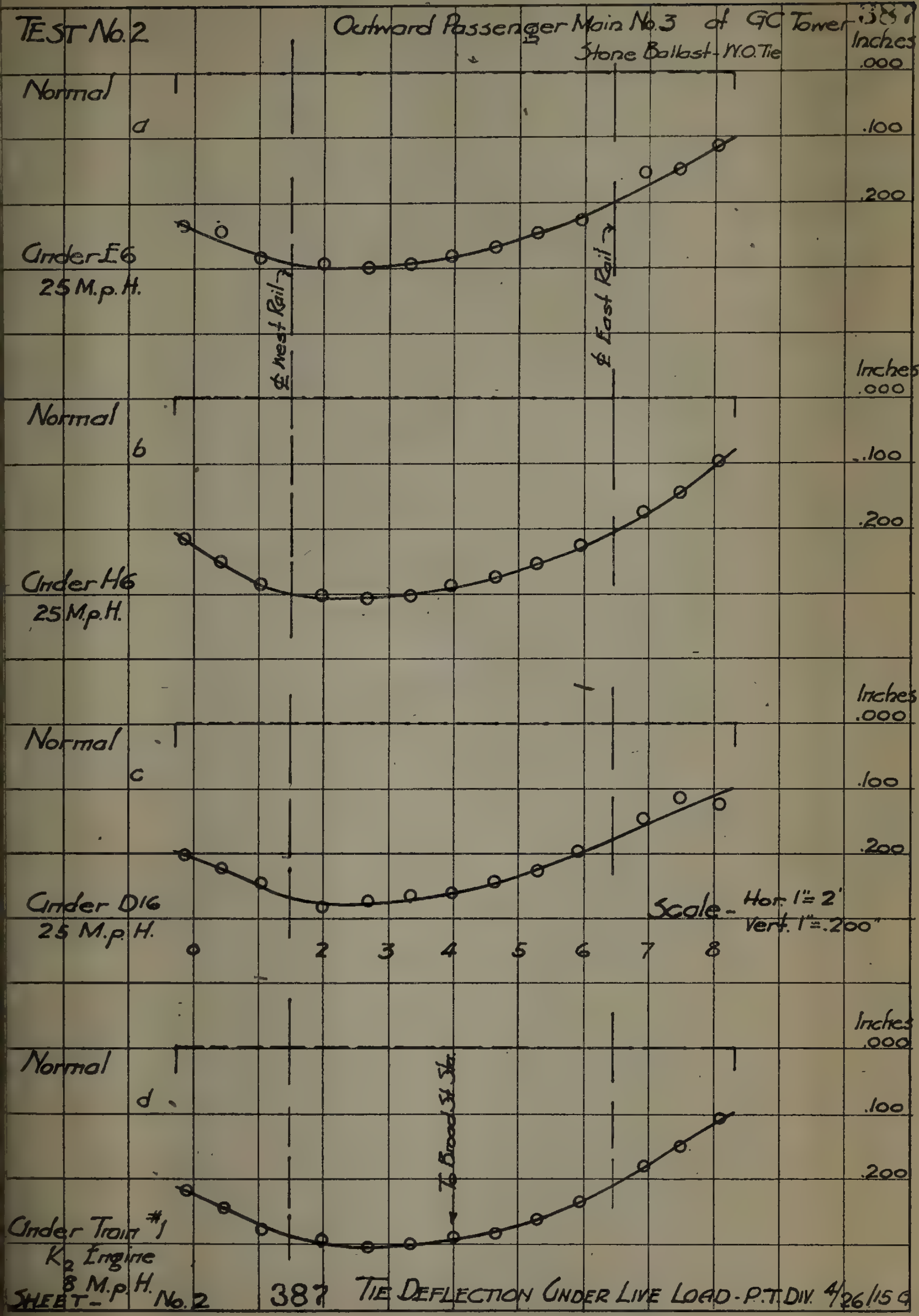
SHEET #1 – Main Passenger Track No 1 – Near 37th St
a – E6 Engine – Speed 50 M.p.H.
b – H6 " " 40 " "
c – D16 " " 30 " "
d – Train #2 – E3 Engine " 50 " "

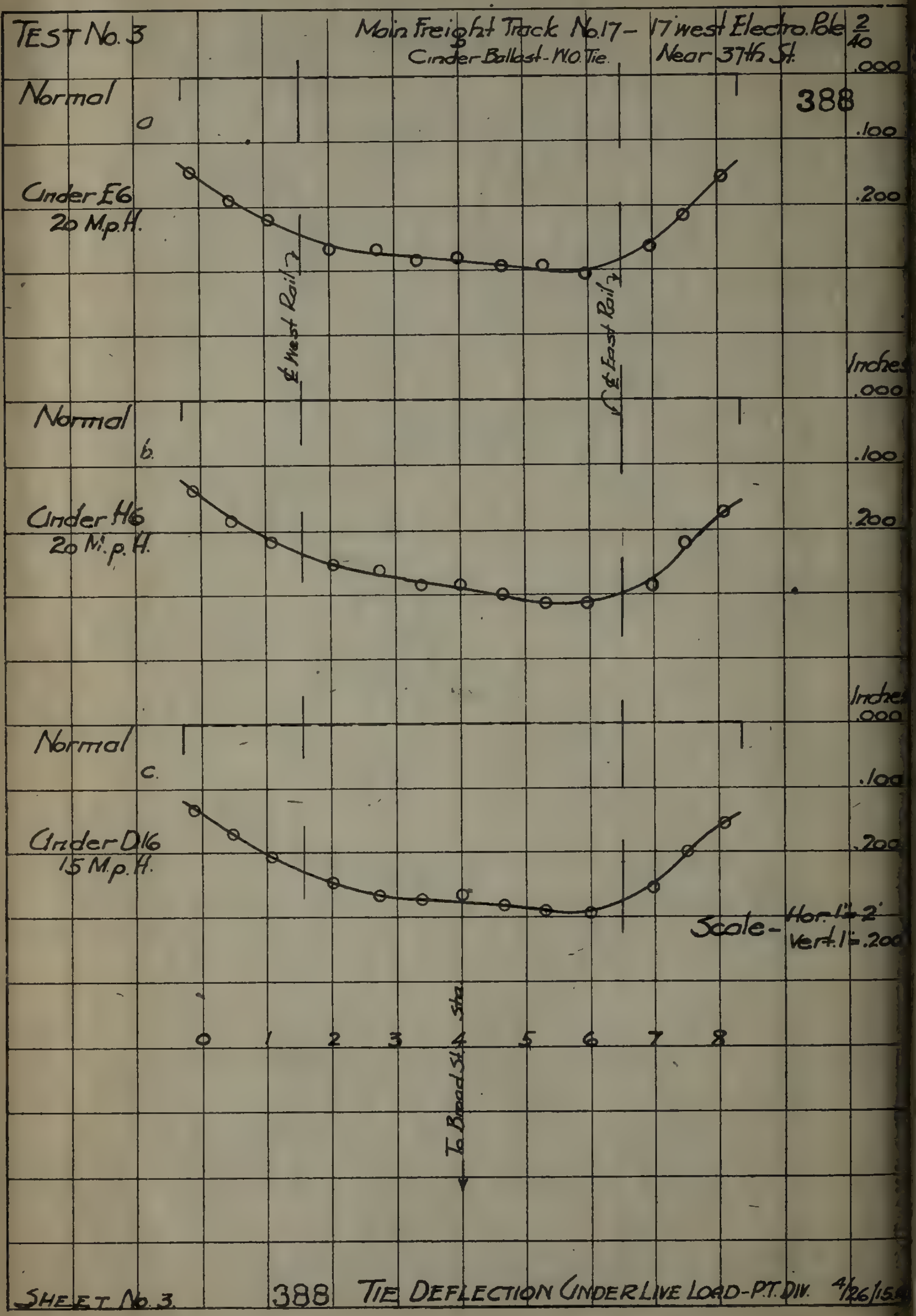
SHEET #2 Main Passenger Track Outward #3 at GC Tower
a – E6 Engine Speed 25 M.p.H.
b – H6 " " 25 " "
c – D16 " " 25 " "
d – Train No 1 – K_2 Engine " 8 " "

SHEET #3 Main Freight Track No 17 Opposite #1 Near 37th St
a – E6 Engine Speed 20 M.p.H.
b – H6 " " 20 " "
d – D16 " " 15 " "

SHEET #4 Schuylkill River Branch – Eastward Frt. Track 375' W 30th St.
a – E6 Engine Speed 15 M.p.H.
b – H6 " " 15 " "
c – D6 " " 20 " "
d – A4 " " 10 " "


TEST-No.1
Main Passenger Track No.1
Stone Ballast
N.O. Tie
17' West - Electro. Pole 2/40
Near 37th. St.
386
Inches
.000
.100
.200
Normal
a.
Under E6
50 Mp.H.
West Rail ℄
East Rail ℄
Inches
.000
.100
.200
Normal
b.
Under H6
40 M.p.H.
Inches
.000
.100
.200
Normal
c
Under D16
30 M.p.H.
Scale - Hor. 1" = 2'
Vert. 1" = .200"
0
1
2
3
4
5
6
7
8
Inches
.000
.100
.200
Normal
d.
Under Train #2
E 3 Engine
50 M.p.H.
To Broad St. Sta.
Sheet No. 1
386 Tie Deflection Under Live Load
P.T. Div. 4/26/15


TEST No. 2
Outward Passenger Main No. 3 at GC Tower
Stone Ballast - N.O. Tie
387
Inches
.000
.100
.200
Normal
a
Under E6
25 M.p.H.
℄ West Rail
℄ East Rail
Inches
.000
.100
.200
Normal
b
Under H6
25 M.p.H.
Inches
.000
.100
.200
Normal
c
Under D16
25 M.p.H.
Scale - Hor. 1" = 2'
Vert. 1" = .200"
0
2
3
4
5
6
7
8
Inches
.000
.100
.200
Normal
d
To Broad St. Sta.
Under Train #1
K2 Engine
8 M.p.H.
SHEET - No. 2
387
TIE DEFLECTION UNDER LIVE LOAD - P.T. DIV. 4/26/15 G


TEST No. 3
Main Freight Track No. 17 - 17 west Electro. Pole 2/40
Cinder-Ballast - W.O. Tie. Near 37th St.
388
Normal
a
Under E6 20 M.p.H.
.000
.100
.200
℄ West Rail
℄ East Rail
Inches
.000
Normal
b.
.100
Under H6 20 M.p.H.
.200
Inches
.000
Normal
c.
.100
Under D16 15 M.p.H.
.200
Scale - Hor. 1" = 2' Vert. 1" = .200
0
1
2
3
4
5
6
7
8
To Broad St. Sta.
SHEET No. 3.
388
TIE DEFLECTION UNDER LIVE LOAD - P.T. DIV. 4/26/15

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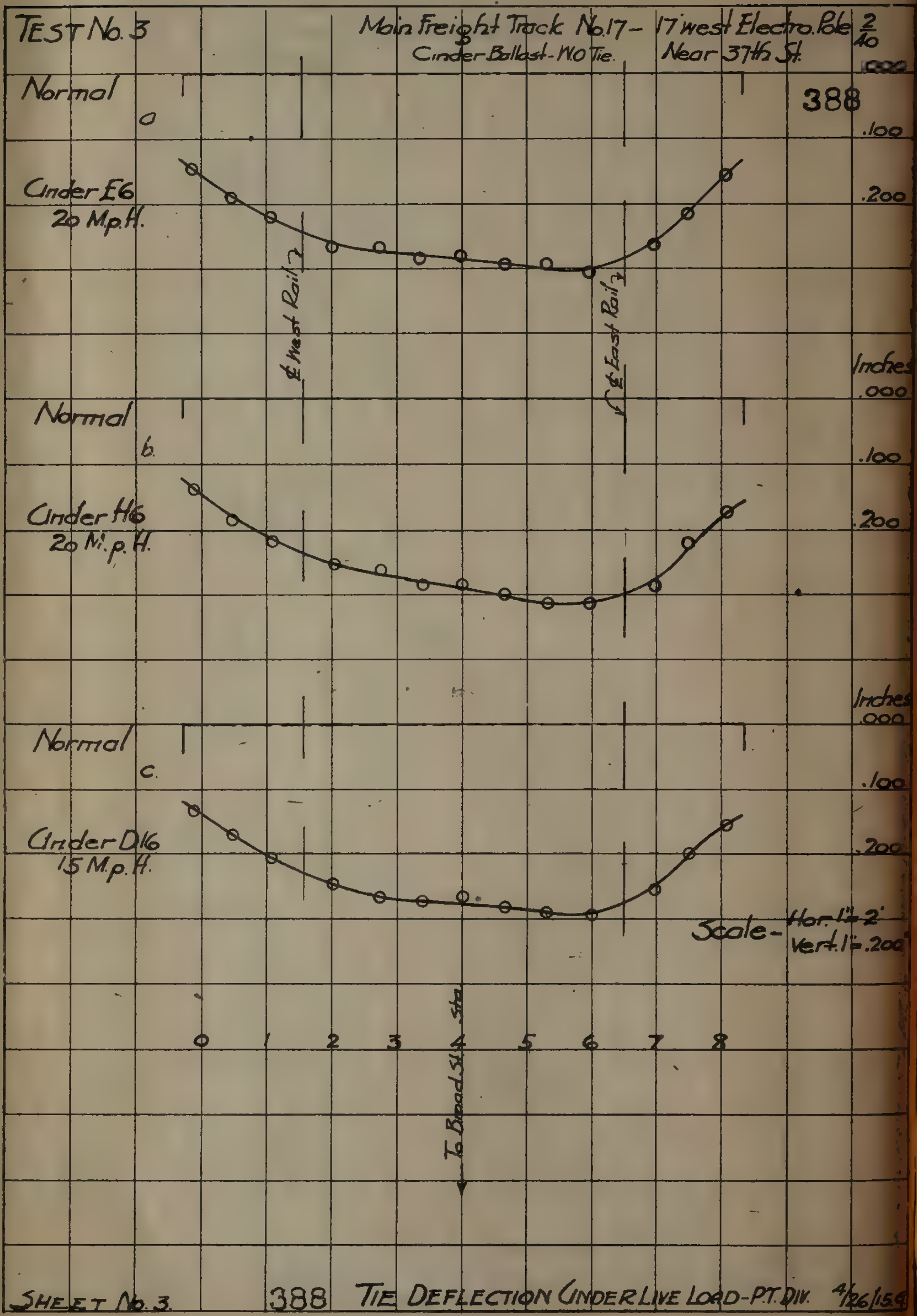
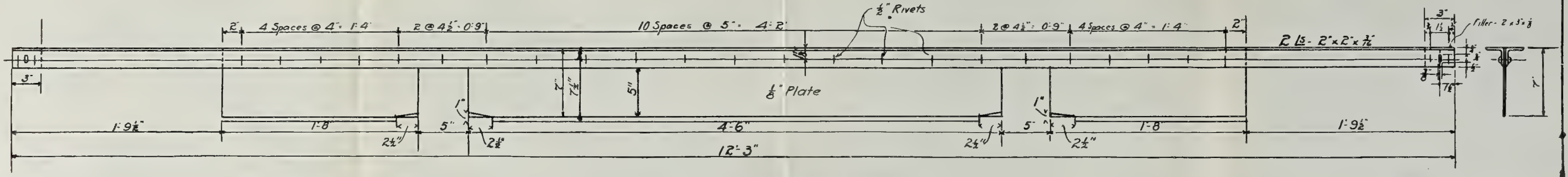
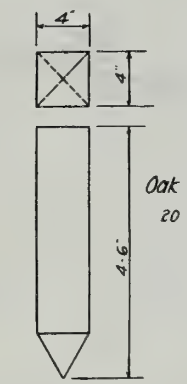
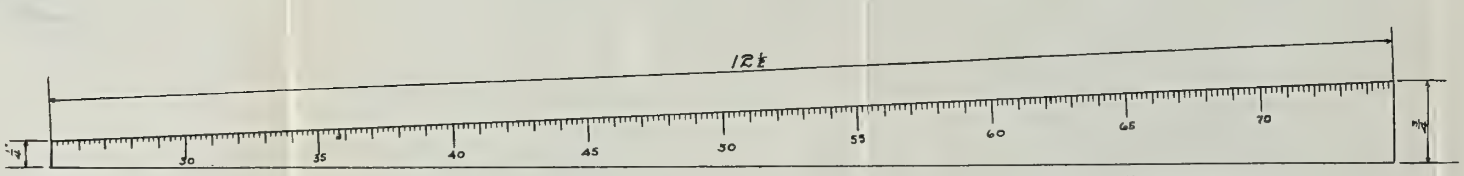

TEST No. 3
Main Freight Track No.17 - 17' west Electro. Pole 2/40
Cinder-Ballast - W.O Tie.
Near 37th St.
388
Normal
a
Under E6
20 M.p.H.
℄ West Rail
℄ East Rail
.000
.100
.200
Inches
Normal
b.
Under H6
20 M.p.H.
.000
.100
.200
Inches
Normal
c.
Under D16
15 M.p.H.
.000
.100
.200
Scale - Hor. 1" = 2' Vert. 1" = .200"
0
1
2
3
4
5
6
7
8
Sta.
To Broad St. Sta.
SHEET No. 3.
388
TIE DEFLECTION UNDER LIVE LOAD - P.T. DIV. 4/26/15



STRAIGHT EDGE One required as shown



Oak Stake
20 Required



To be made of 1/16" Steel - polished - and
accurately graduated as shown

Phila. September, 1914

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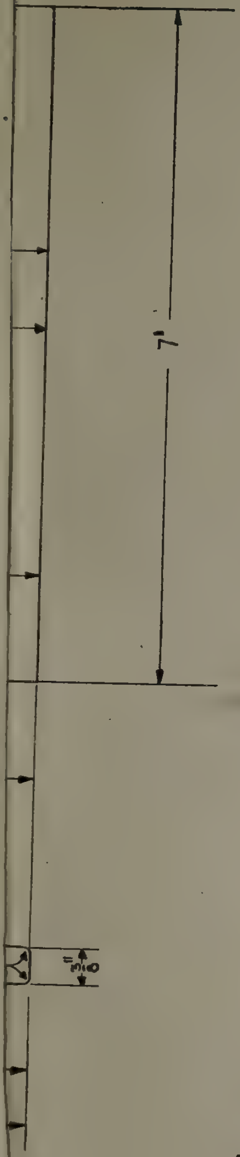

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62078-C

PENNA. RAILROAD

TIE PLATE

TYPE 8

OCTOBER 1914.

REVISED:-
FEB. 1915.
OCT. 1915.
FEB. 1916.

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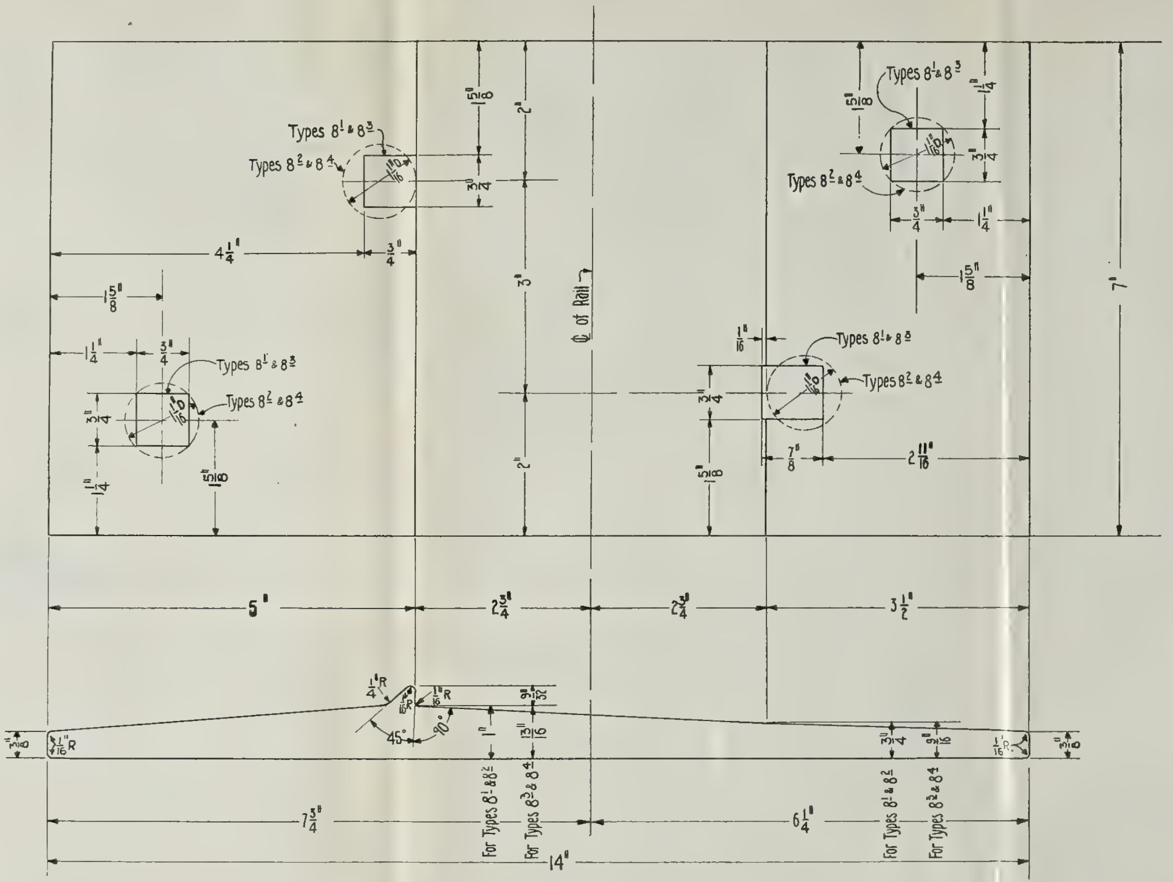

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PENNA. RAILROAD

TIE PLATE

TYPE 8

OCTOBER 1914.

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FEB. 1916.

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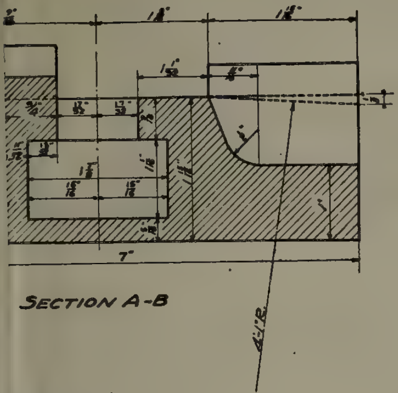
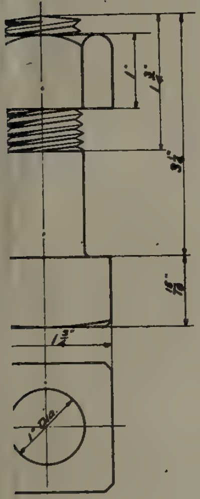
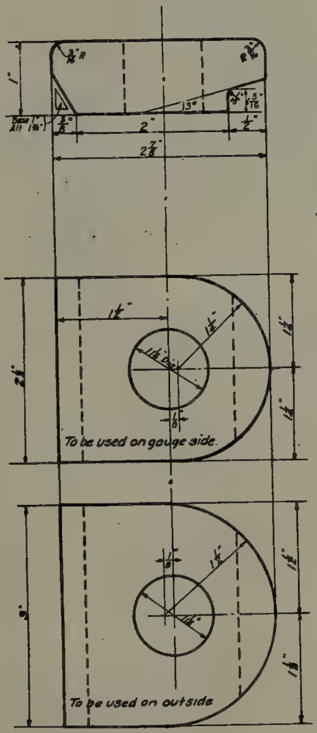


SECTION A-B





CLIP

TYPES 9 & 10
PENNA. LINES WEST OF PITTSBURGH

SCREW SPIKE EXPERIMENTS

CAST IRON TIE PLATE CHAIR
FOR SCREW SPIKES
7"x14" FOR 100 LB. P.S. RAIL

Scale Full Size
Sept. 1914
Revised Dec. 1914
Office Chief Engr. M. of W.
No 16476
Sheet 1 of 5.

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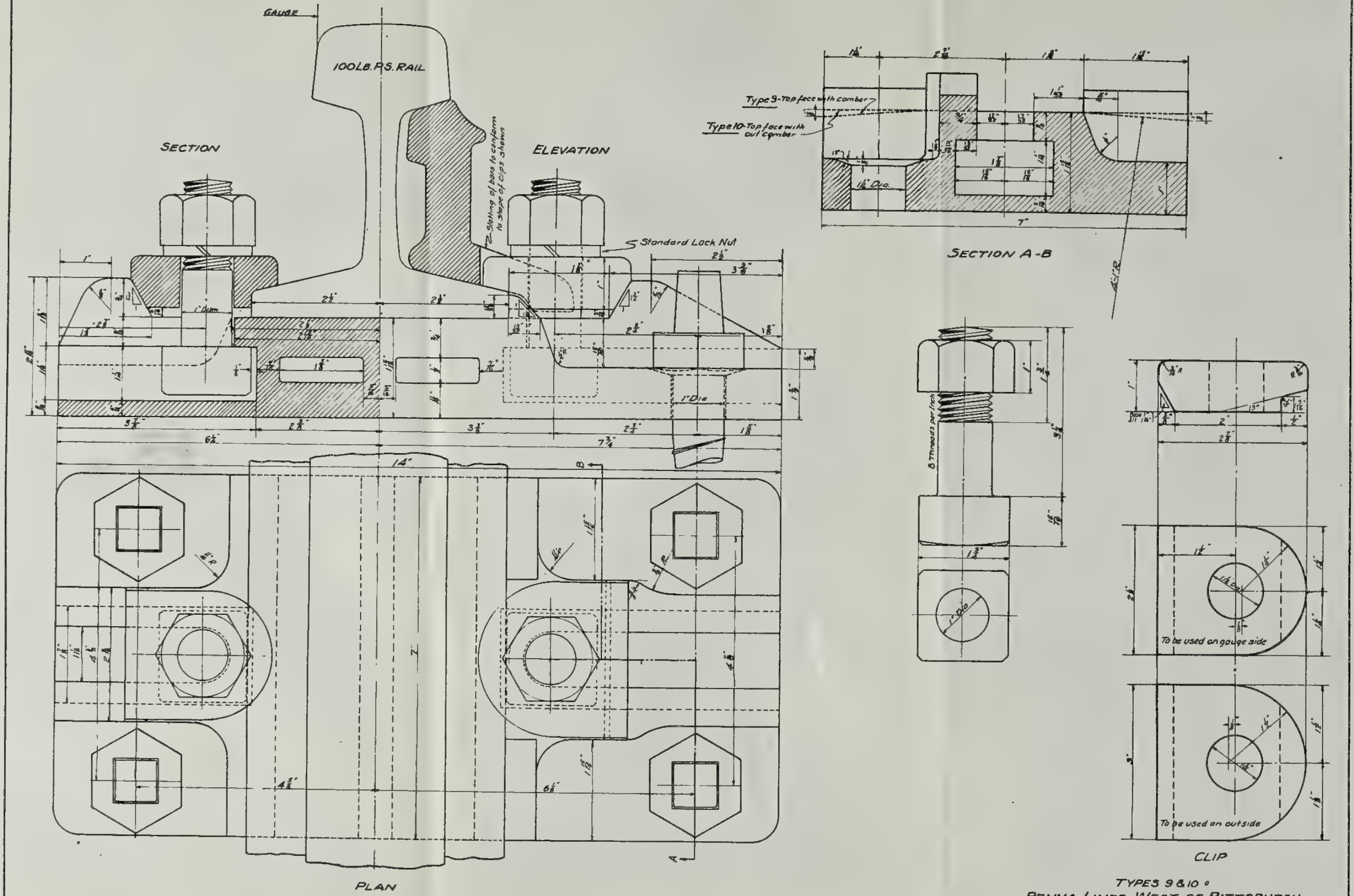

TYPES 9 & 10 °
PENNA. LINES WEST OF PITTSBURGH

SCREW SPIKE EXPERIMENTS

CAST IRON TIE PLATE CHAIR
FOR SCREW SPIKES
7"x14" FOR 100 LB. P.S. RAIL

WEIGHT OF CASTING = LBS.

Scale Full Size
Sept. 1914
Revised Dec. 1914
Office Chief Engr. M. of W.
No 16476
Sheet 1 of 5.

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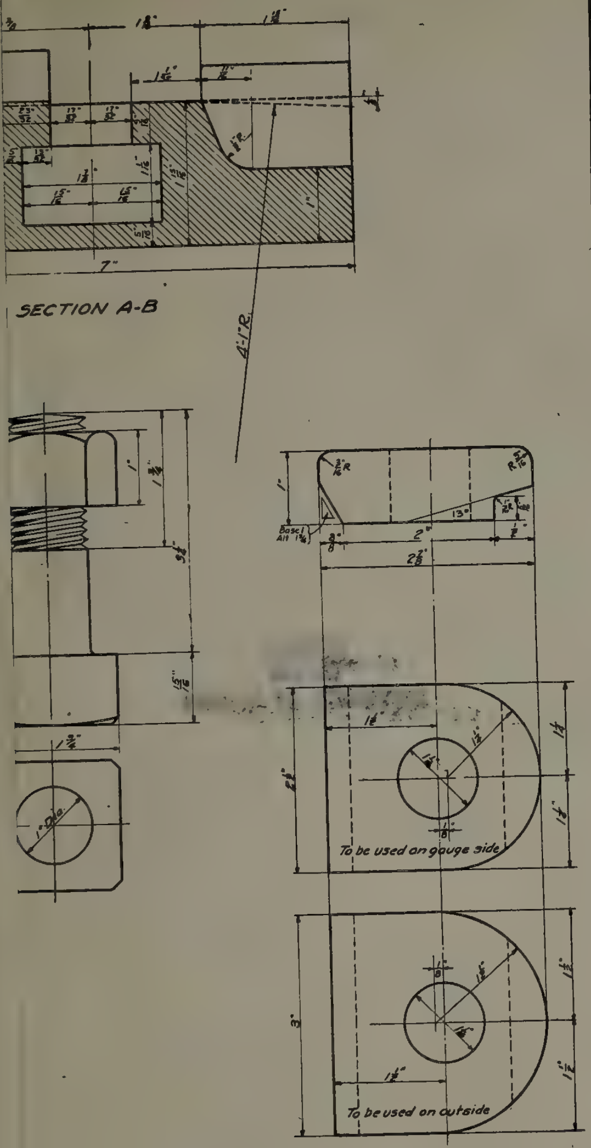

TYPES 11 & 12
PENNA LINES WEST OF PITTSBURGH.
SCREW SPIKE EXPERIMENTS
CAST IRON TIE PLATE CHAIR
FOR SCREW SPIKES.
7"X16" FOR 100 LB. P.S. RAIL
Scale Full Size
Sept. 1914
Revised Dec. 1914
Office Chief Engr. M. of W.
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Sheet 2 of 5

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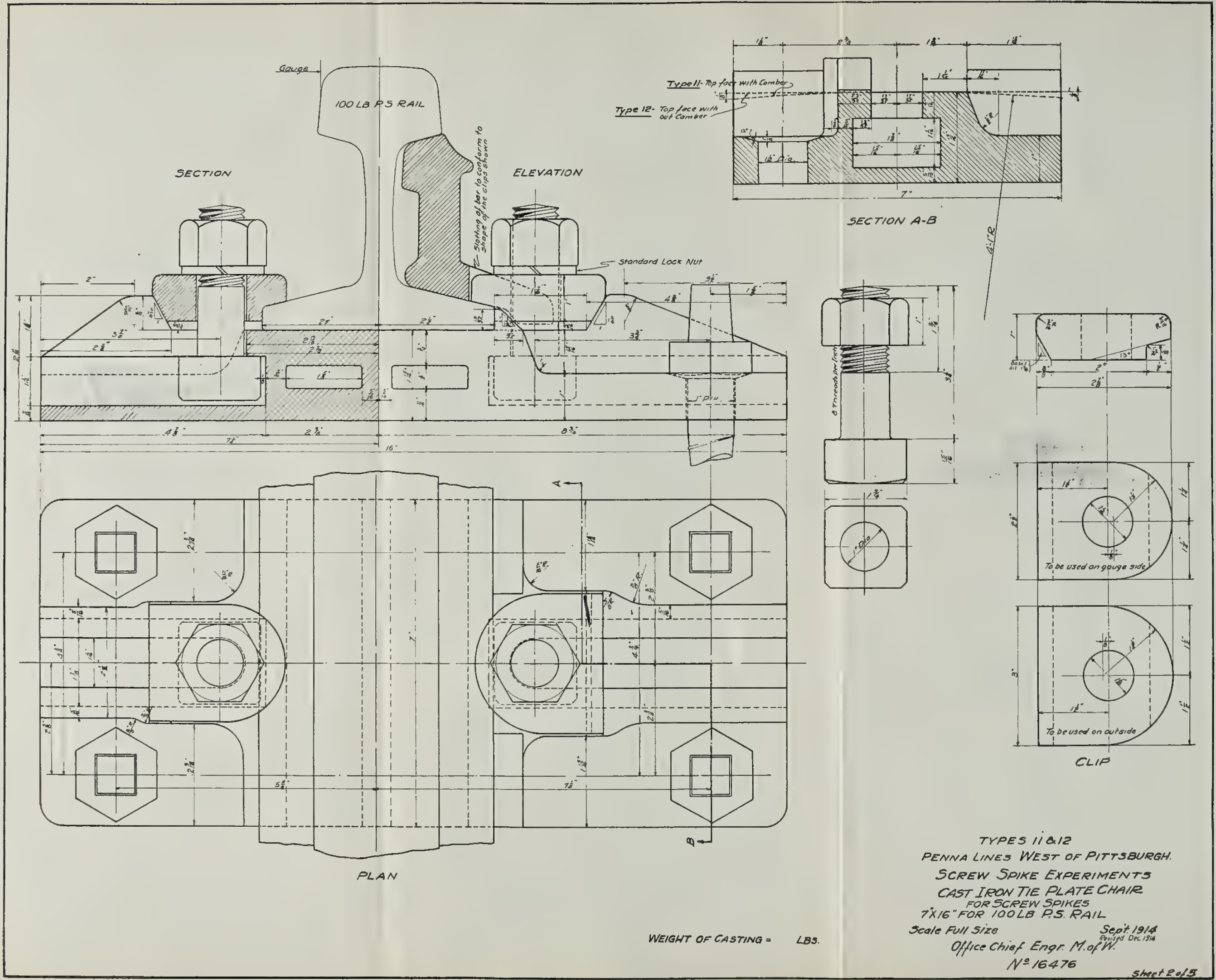

WEIGHT OF CASTING = LBS.

TYPES 11 & 12
PENNA LINES WEST OF PITTSBURGH.
SCREW SPIKE EXPERIMENTS
CAST IRON TIE PLATE CHAIR
FOR SCREW SPIKES
7"X16" FOR 100 LB P.S. RAIL
Scale Full Size
Sept 1914
Revised Dec. 1914
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Sheet 2 of 5

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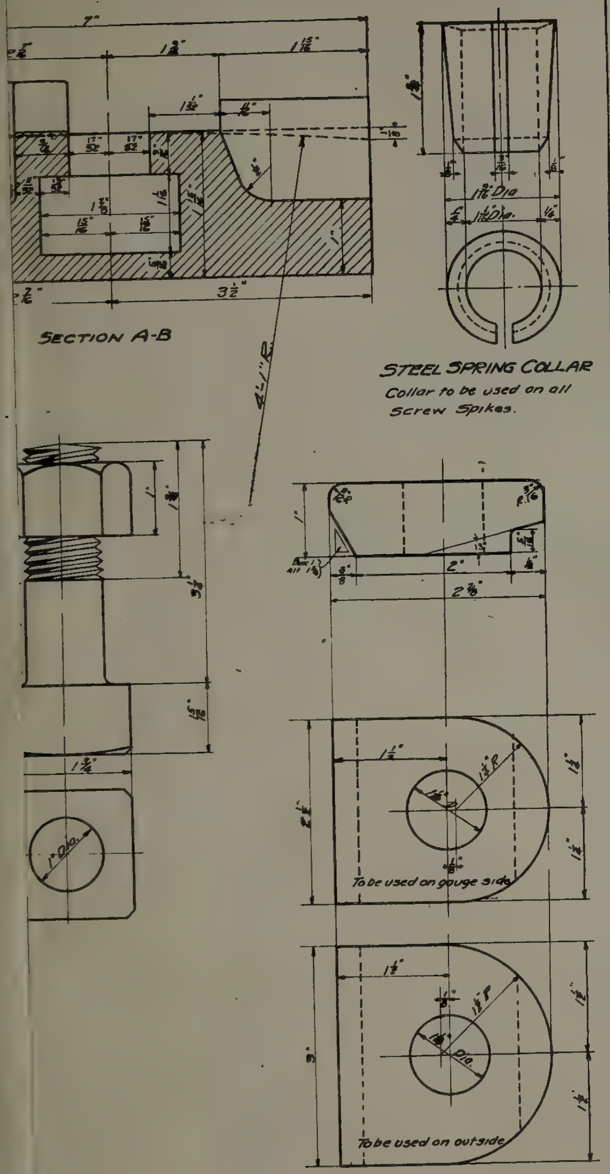

SECTION A-B

STEEL SPRING COLLAR
Collar to be used on all
Screw Spikes.

CLIP

ALTERNATE TO TYPES 9-10
PENNA. LINES WEST OF PITTSBURGH.
SCREW SPIKE EXPERIMENTS
CAST IRON TIE PLATE CHAIR
FOR SCREW SPIKES
7"X14" FOR 100LB. PS RAIL

Scale Full Size

Sept 1914.
Revised Dec 1914

Office Chief Engr M of W
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Sheet 3 of 3.

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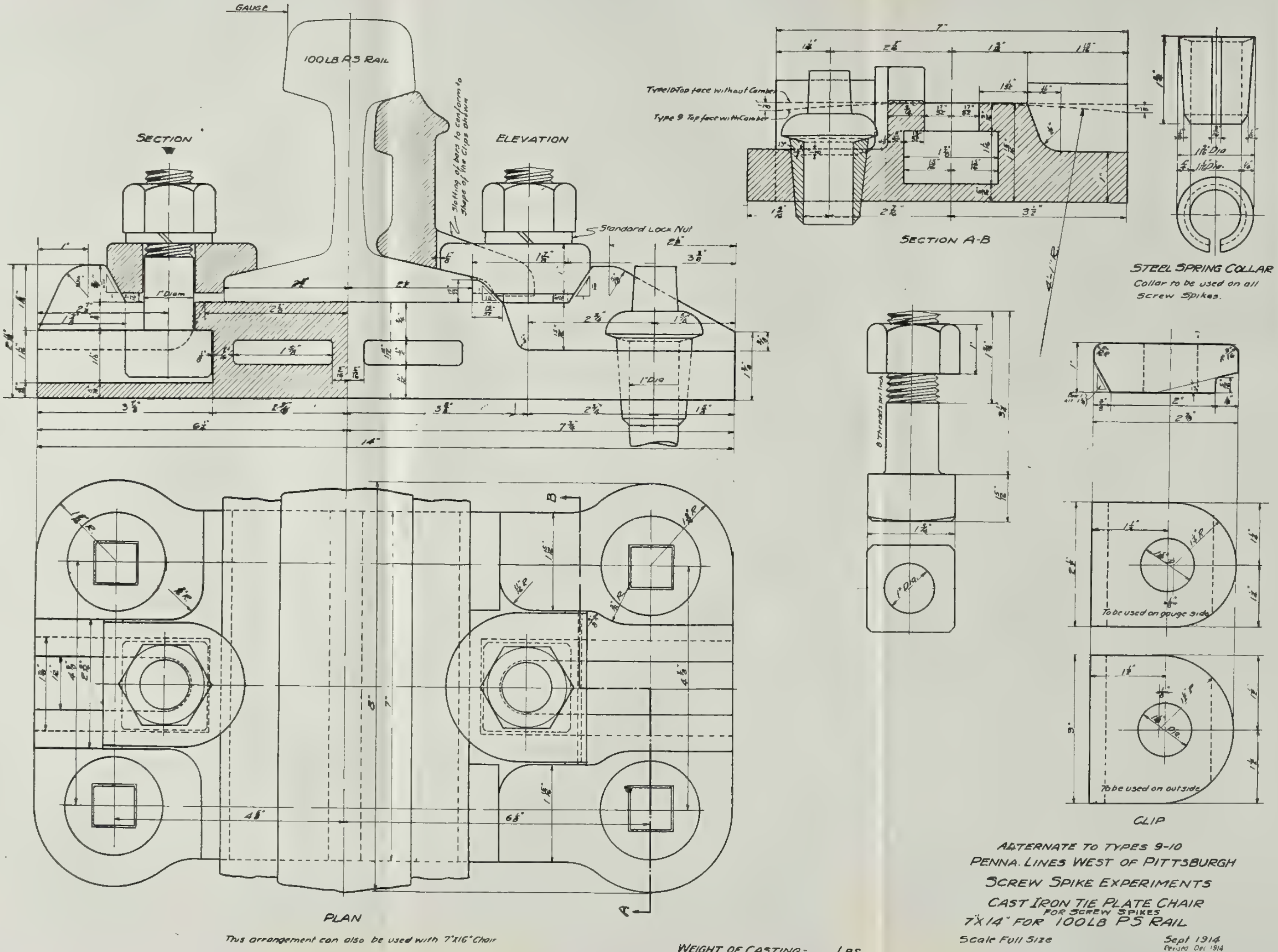
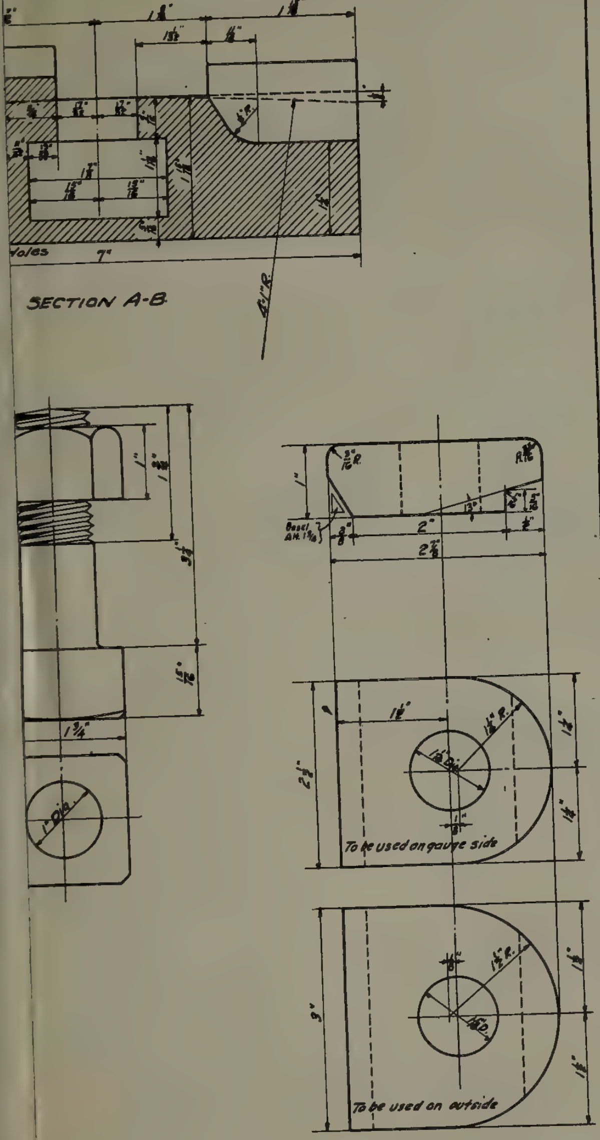


This arrangement can also be used with 7"x16" Chair

WEIGHT OF CASTING = LBS

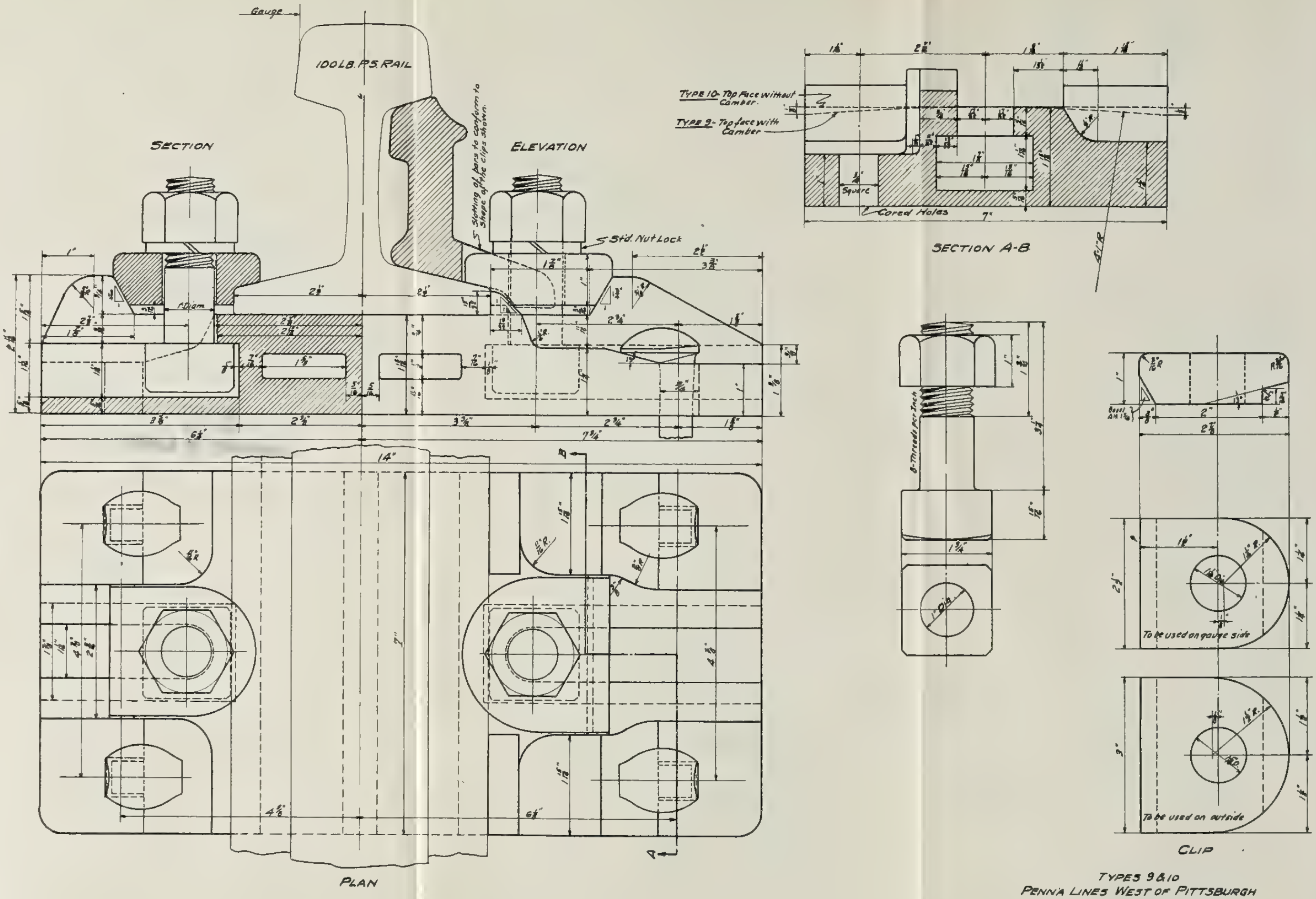
ALTERNATE TO TYPES 9-10
PENNA. LINES WEST OF PITTSBURGH
SCREW SPIKE EXPERIMENTS
CAST IRON TIE PLATE CHAIR
FOR SCREW SPIKES
7"x14" FOR 100 LB P.S. RAIL
Scale Full Size
Sept 1914
Revised Dec 1914
Office Chief Engr M of W
Nº 16476

Sheet 3 of 3.



TYPES 9&10
PENN'A. LINES WEST OF PITTSBURGH
SCREW SPIKE EXPERIMENTS.
CAST IRON TIE PLATE CHAIR
FOR NAIL SPIKES
7"x14" FOR 100 LB P.S. RAIL

Scale Full Size.
Sep't 1914.
Revised Dec 1914
Office Chief Engr. M. of W
Nº 16476
Sheet 4 of 5.



TYPES 9 & 10
PENN'A LINES WEST OF PITTSBURGH

SCREW SPIKE EXPERIMENTS.

CAST IRON TIE PLATE CHAIR
FOR NAIL SPIKES
7"x 14" FOR 100 LB P.S RAIL

WEIGHT OF CASTING -   LBS.

Scale Full Size.
Sep't 1914.
Revised Dec 1914
Office Chief Engr. M. of W.
No 16476
Sheet 4 of 5.

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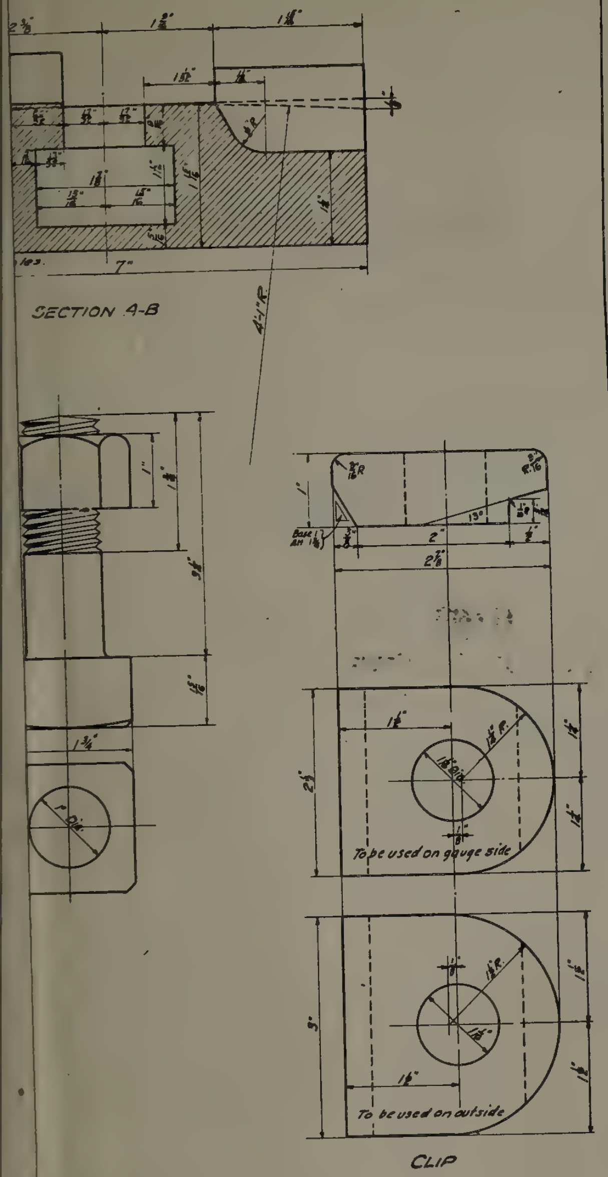

TYPES 11&12
PENN'A. LINES WEST OF PITTSBURGH
SCREW SPIKE EXPERIMENTS
CAST IRON TIE PLATE CHAIR
FOR NAIL SPIKES
7"X16" FOR 100 LB. P.S. RAIL
Scale Full Size
Sept. 1914.
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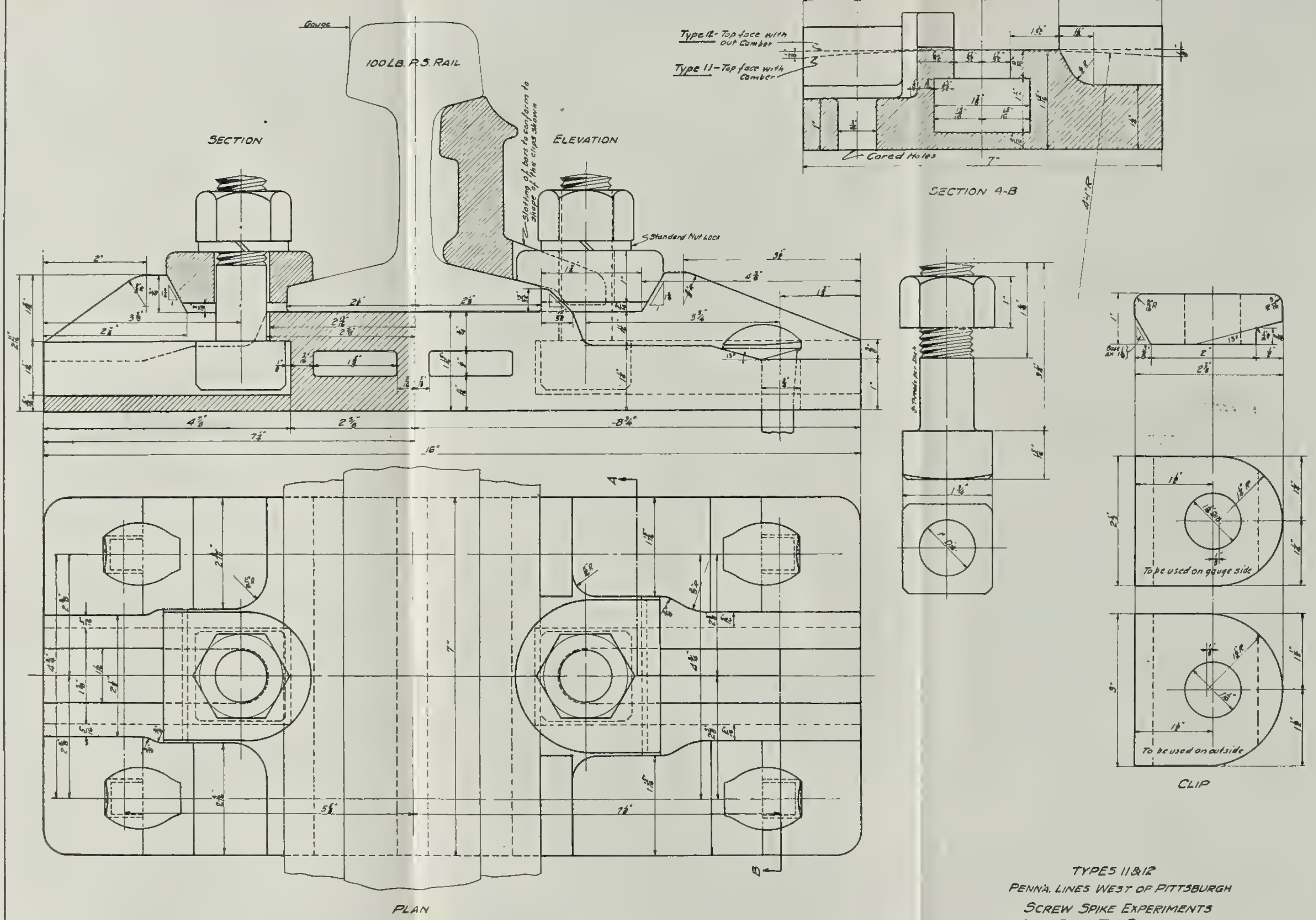

WEIGHT OF CASTING= LBS

TYPES 11&12
PENNA. LINES WEST OF PITTSBURGH
SCREW SPIKE EXPERIMENTS
CAST IRON TIE PLATE CHAIR
FOR NAIL SPIKES
7"X16" FOR 100 LB. P.S. RAIL
Scale Full Size Sept. 1914
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Sheet 5 of 5.

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PENNA. RAILROAD

TIE PLATE

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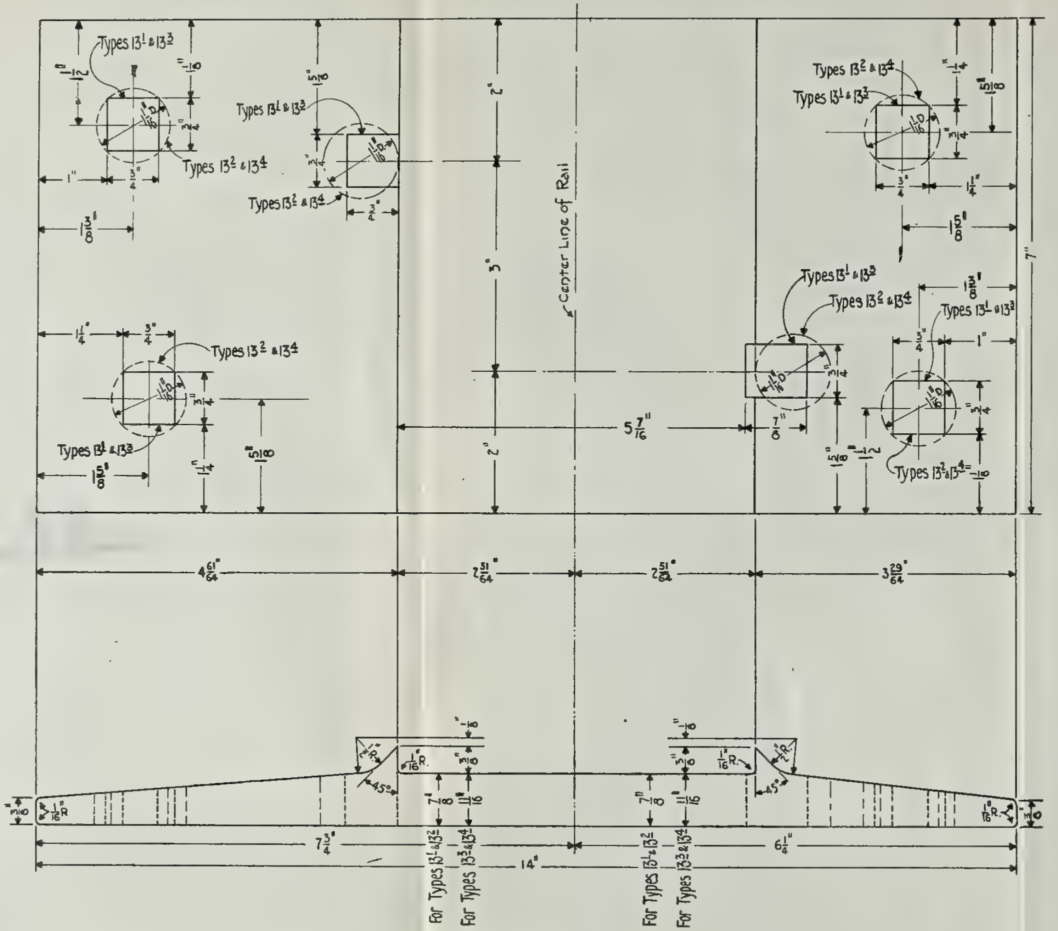

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PENNA. RAILROAD

TIE PLATE

TYPE 13

OCTOBER 1914.

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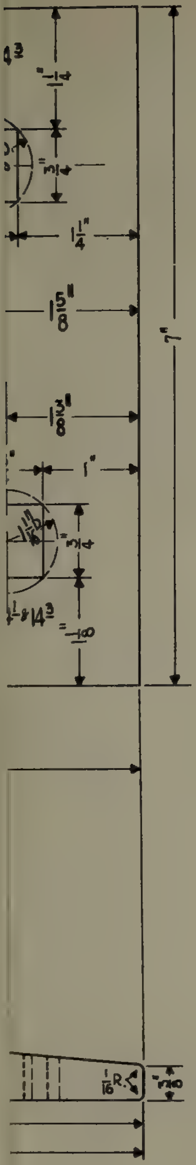

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62080-C

PENNA. RAILROAD

TIE PLATE

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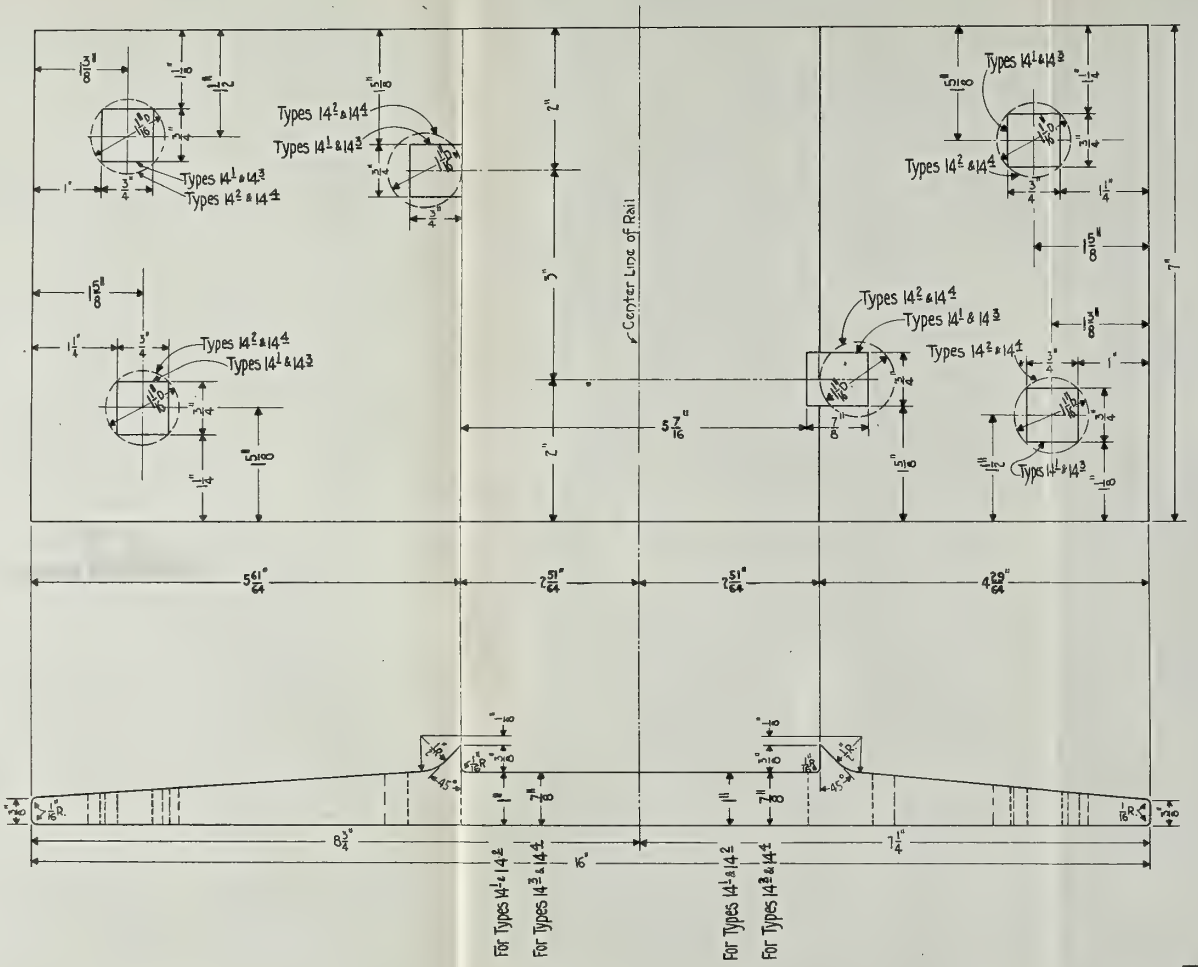

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62080-C
PENNA. RAILROAD
TIE PLATE
TYPE 14
OCTOBER 1914.

REVISED:-
FEB 1915.
OCT. 1915.
FEB. 1916.

Approved for experimental use.

W. G. Coyle

ENGINEER M.W.

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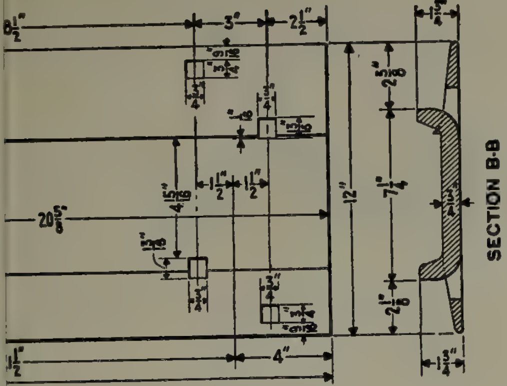
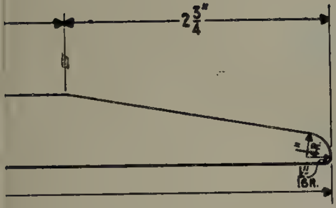




62175-A
REVISED:-
AUG. 1915.

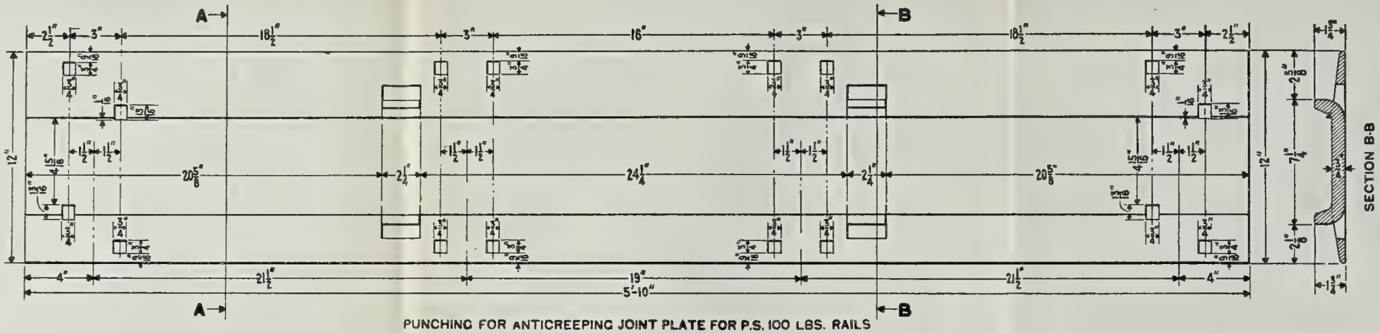
TIE PLATE AND ANTICREEPING JOINT PLATE

PHILA DECEMBER 1914

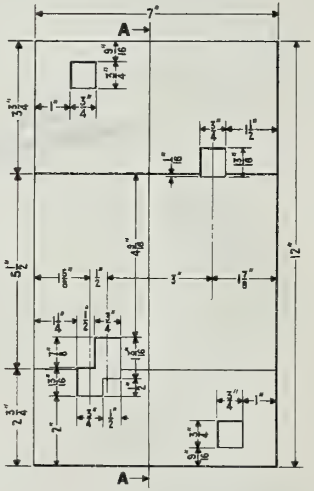
Approved for Experimental use

Engineer M. W.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

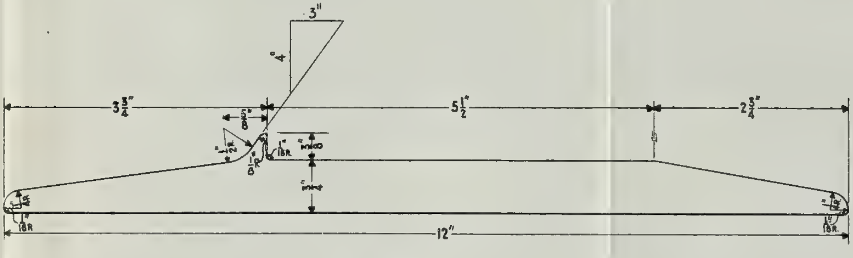


PUNCHING FOR ANTICREEPING JOINT PLATE FOR P.S. 100 LBS. RAILS



PUNCHING FOR HEAVY TIE PLATE

This Tie Plate for use on curves where there is excessive cutting of the ties.



SECTION A-A

NOTE:-

Requisitions must state when Tie Plates are for use on open floor Bridges and Trestles and when so specified the Tie Plate shall be 10½ in. wide instead of 7 in.

62175-A
REVISED:-
AUG. 1915.

HEAVY TIE PLATE AND ANTICREEPING JOINT PLATE

PHILA DECEMBER 1914

Approved for Experimental use

W. G. Coyle
Engineer M. W.

DRAWN BY F.J.A.
CHECKED BY

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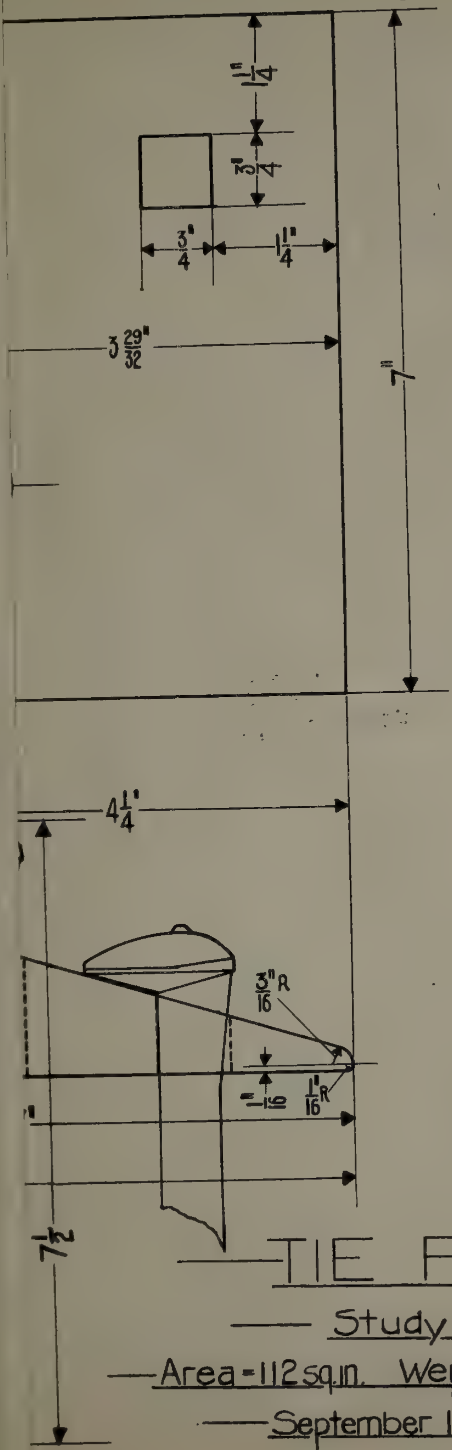
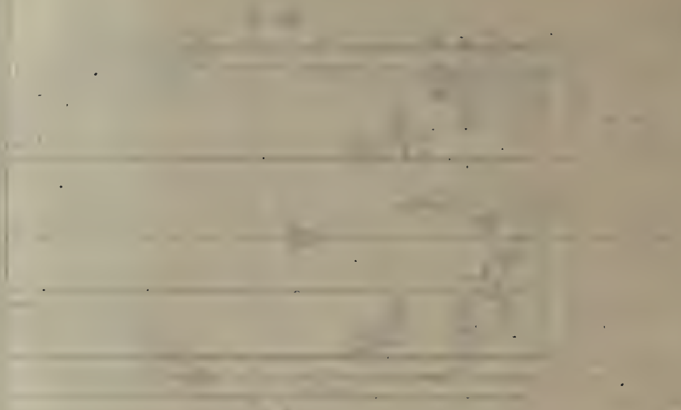


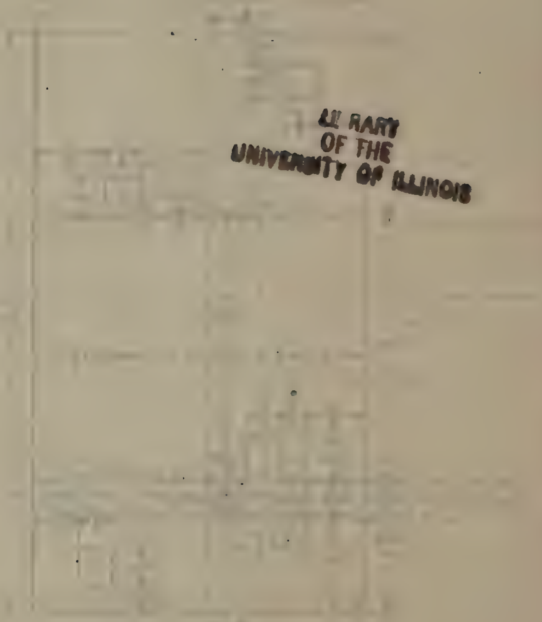
TIE PLATE

Study No. 4

Area = 112 sq.in. Weight 34.67 lbs.

September 1914





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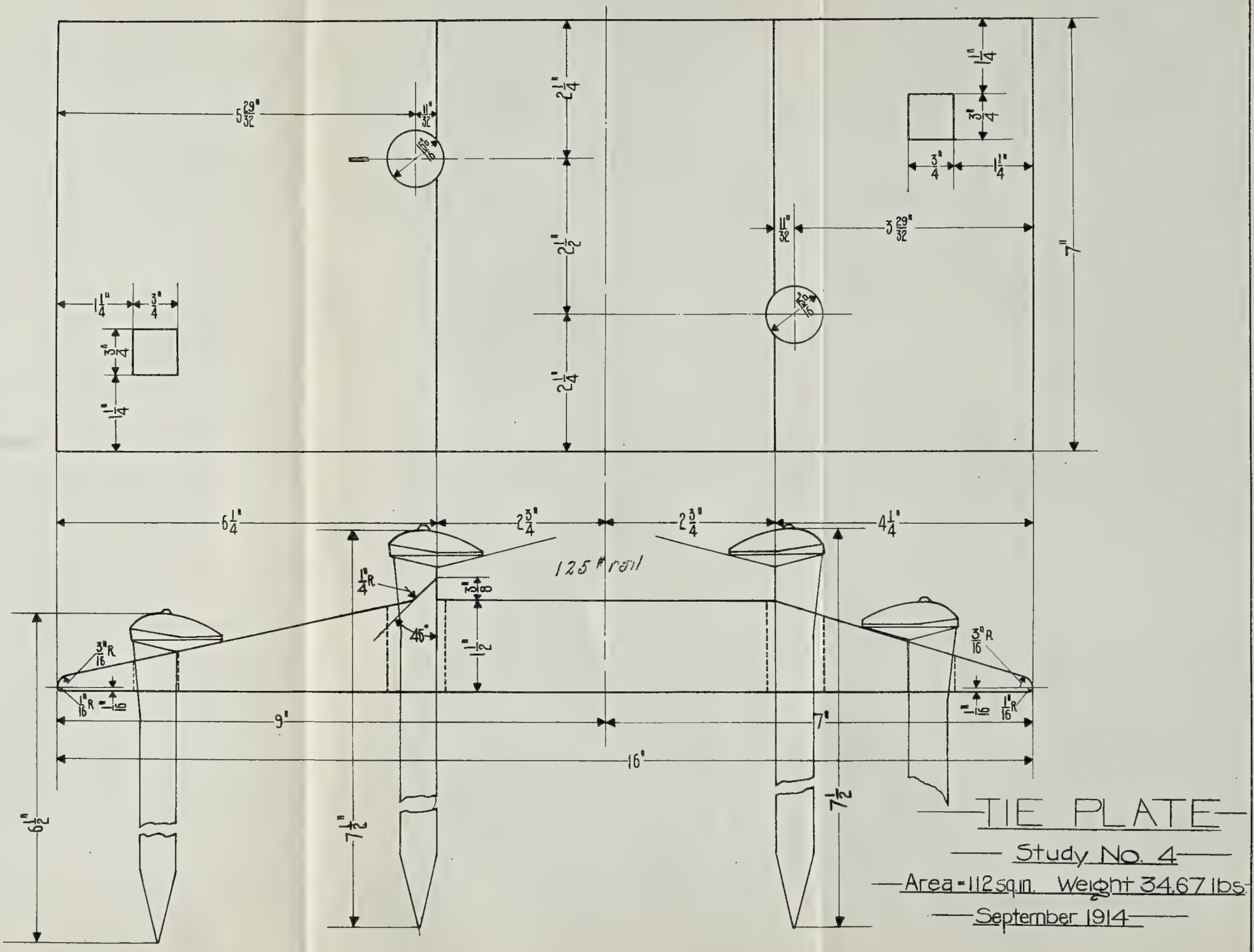

TIE PLATE

Study No. 4

Area = 112 sq. in. Weight 34.67 lbs.

September 1914

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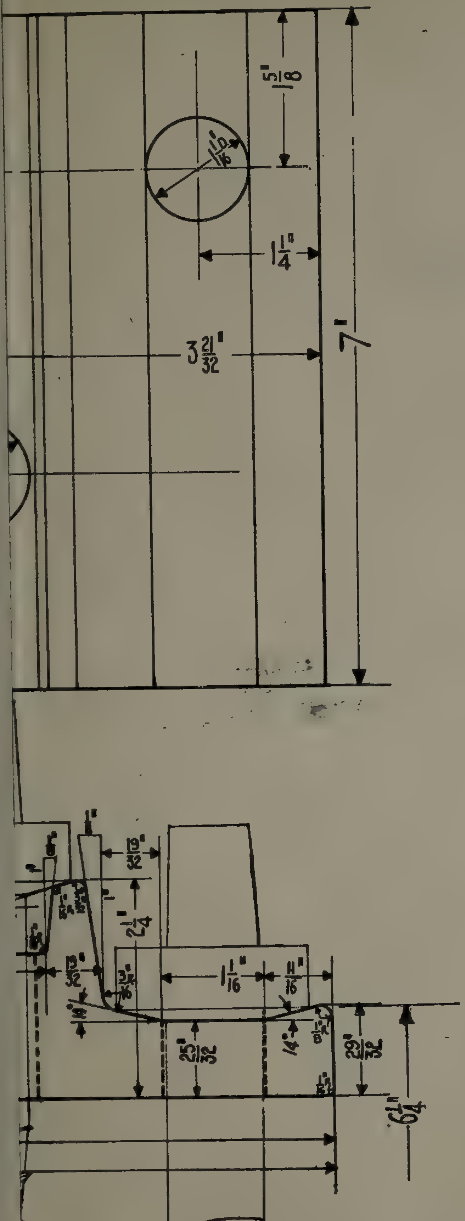

TIE PLATE

Study No. 5.

Area = 112 sq.in. Weight = 39.16 lbs.

September, 1914.

Issued September 23, 1914

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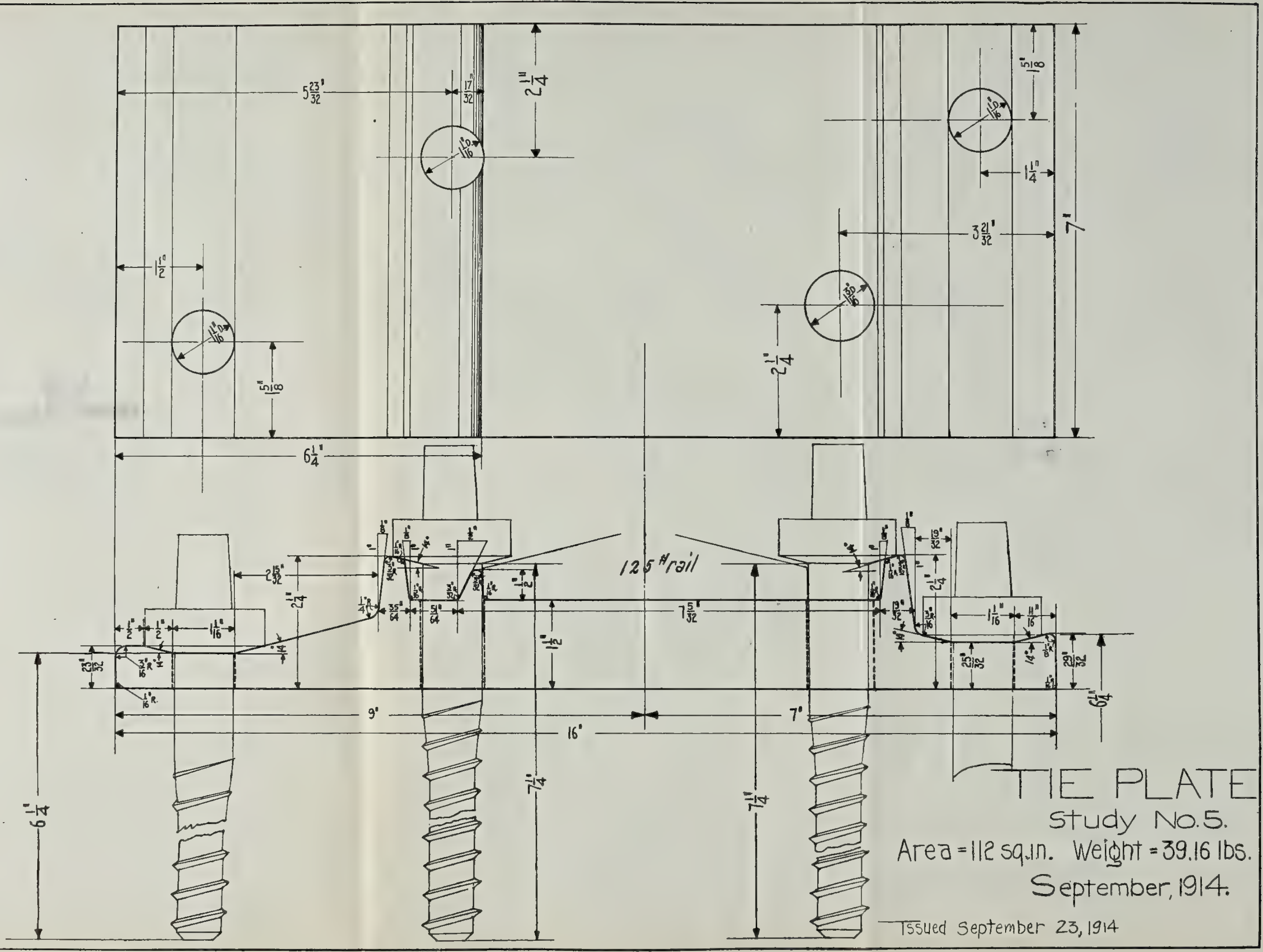

TIE PLATE

Study No. 5.

Area = 112 sq. in. Weight = 39.16 lbs.

September, 1914.

Issued September 23, 1914

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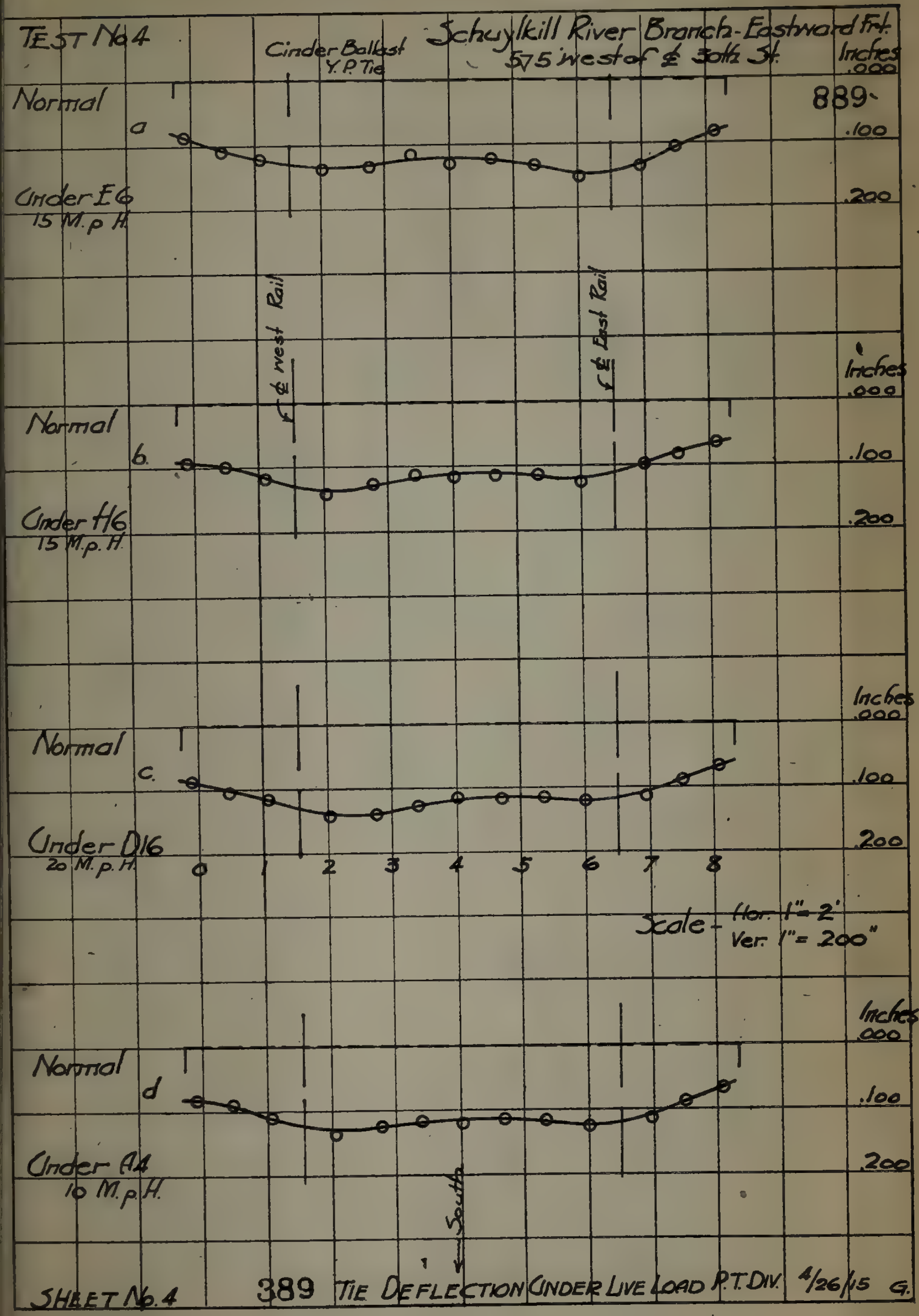
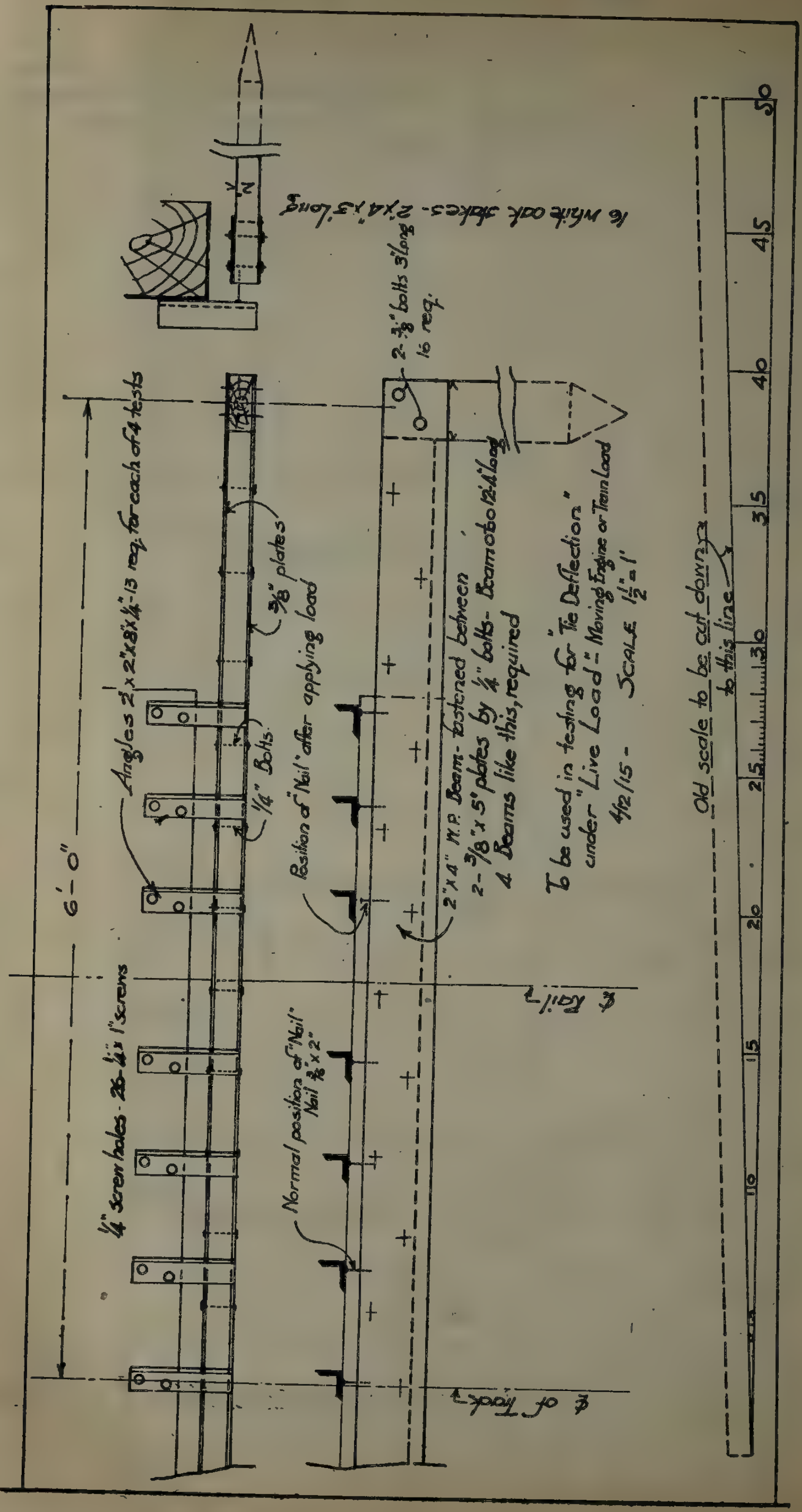

Test No 4
Cinder Ballast
Y.P. Tie
Schuylkill River Branch-Eastward Frt.
575 west of ℄ 30th St.
Inches
.000
889
.100
.200
Normal
a
Under E6
15 M.p.H.
℄ West Rail
℄ East Rail
Inches
.000
Normal
b
.100
Under H6
15 M.p.H.
.200
Inches
.000
Normal
c
.100
Under D16
20 M.p.H.
.200
0
1
2
3
4
5
6
7
8
Scale - Hor. 1" = 2'
Ver. 1" = 200"
Inches
.000
Normal
d
.100
Under A4
10 M.p.H.
.200
South
Sheet No. 4
389
Tie Deflection Under Live Load P.T. Div. 4/26/15 G.


16 white oak stakes - 2"x4"x3' long
2-3/8" bolts 3' long
16 req.
Angles 2 3/8 x 2" x 8" x 1/4" - 13 req. for each of 4 tests
3/8" plates
1/4" Bolts
6'-0"
Position of "Nail" after applying load
2"x4" Y.P. Beam - fastened between
2 - 3/8" x 5" plates by 1/4" bolts - Beam also 12'-4' long
4 Beams like this, required
To be used in testing for "Tie Deflection"
under "Live Load" - Moving Engine or Train Load
4/12/15 - SCALE 1 1/2" = 1'
Old scale to be cut down
to this line
1/4" Screw holes - 26 - 1/4" x 1" Screws
Normal position of "Nail"
Nail 3/8" x 2"
℄ Rail
℄ of Track
50
45
40
35
30
25
20
15
10

September 17, 1914.

Communication from Mr. W. W. Atterbury to Mr. S. C. Long.

Dated August 27, 1914, and all papers.

Subject: Splices, tie-plates, spikes, etc., for use in connection with new 125-lb. rail.

Respectfully returned to
Mr. S. C. Long, General Manager.

Following our memorandum of August 28, we beg to advise that the Committee on Screw-Spike Test met at Altoona on September 3, after inspecting the experimental track at Birmingham, and very carefully and thoroughly considered and discussed the question of tie-plate dimensions, having before it Mr. Rea's memorandum of August 20, your reply of August 22, and Mr. Rea's reference to you of August 26.

The Committee unanimously agreed to repeat its recommendation of February 25, 1914, as to further tests of large tie-plates, as follows:

Type 8—Rolled Steel—7 in. by 14 in. by ½ in. to ¾ in.
Type 9—Malleable Cast-Iron—7 in. by 14 in. by 2 in.—Cambered.
Type 10—Malleable Cast-Iron—7 in. by 14 in. by 2 in.—Flat
Type 11—Malleable Cast-Iron—7 in. by 16 in. by 2 in.—Cambered.
Type 12—Malleable Cast-Iron—7 in. by 16 in. by 2 in.—Flat.
Type 13—Rolled Steel—7 in. by 14 in. by ¾ in.
Type 14—Rolled Steel—7 in. by 16 in. by ¾ in.

As you will remember, these experiments were postponed on account of financial conditions, but during the summer it was decided to proceed with the test of Type 13, and we wrote to the Purchasing Agent on August 4 inquiring as to the cost of rolls, etc., but have not yet received reply.

In addition to the above tests, the Committee now recommends: First, a test to determine the load (including dynamic augment and impact) which each tie-plate is called upon to support in our heaviest service tracks; and, second, steel tie-plates 7 in. by 9¾ in., 7 in. by 10¾ in., 7 in. by 16 in., and 7 in. by 18 in. (each to be of the proper thickness to distribute the load over its entire area with approximately the same uniformity as the 7 in. by 13 in. by 15/16 in. malleable plates used in previous tests—these thicknesses to be computed and then checked by tests of the finished plate), to be made and secured to white oak blocks 7 in. by 7 in. and subjected to repeated applications of the load determined by the first test. The penetration into the wood of the various tie-plates to be measured and the blocks cut and examined microscopically to detect any changes in the structure of the wood.

This test is to determine the area of tie-plate which will best resist repeated applications of the maximum load to which tie-plates are subjected in track.

In carrying out the first part of the second test above mentioned, Mr. Young, Engineer of Tests, has developed that a rolled-steel plate 16 in. long should be 2 in. thick to provide the desired uniformity in distribution of load, but, as plates of this thickness would be unreasonably expensive, we have ordered for trial in track 200 tie-plates 7 in. by 16 in. by 1½ in., as per blueprints attached (100 of each) (pp. 248-250).

The experiments conducted by the Screw-Spike Committee for the past five years have not led to definite conclusions either as to screw-spikes or tie-plates, and it will likely be some time before positive results are reached, but in the meanwhile we have been improving our standard tie-plate from time to time, using the knowledge gained by the Committee's experiments.

At the inception of the Screw-Spike Test in November, 1909, our standard tie-plate was 7 in. by 9 in. by 7/16 in. One of the first things learned from the experimental track was that the cutting of the tie-plates into the ties was all under the outer edge. Accordingly, in January, 1911, ¾ in. was added to the outer end of the plate, increasing the distance from the center of the rail to the outer end of the tie-plate from 4½ in. to 5¼ in. In January, 1913, ½ in. was added to the side, making the dimensions 9¾ in. by 7½ in. by 7/16 in. After four years' service under our heaviest traffic under the low rail of sharp curves, the 7 in. by 9 in. by 7/16 in. tie-plates in the experimental track began to show a tendency to bend under the outer edge of the rail, and, as it was evident that this tendency would prove more pronounced with the longer tie-plate, the thickness of our standard tie-plate was increased to 9/16 in. in July, 1913. These plates have not shown any indication of bending up to the present time.

In view of the fact that both the 7 in. by 9 in. and the 7½ in. by 9¾ in. tie-plates are cutting into the ties at the outer end of the tie-plate with increasing rapidity as the ties grow older, it was thought that a longer tie-plate should be designed for use under heavy traffic on sharp curves, and we have accordingly arranged for the rolling of tie-plates 7 in. by 10¾ in. by ⅝ in., the distance from center of rail to outer end of plate being 5⅝ in. The width was reduced from 7½ in. to 7 in., for the reason that many cases were found where the tie-plate extended over the edge of the tie, or where the sapwood had split off or decayed, leaving the outer edges of the tie-plate without support. It was not deemed wise to go to a larger area than 7 in. by 10¾ in. for general use at this time, as our experiments have not yet proven the very large sizes economical. The average cutting into the ties at the outer edge of the tie-plates at Birmingham and Wooster, is as follows:

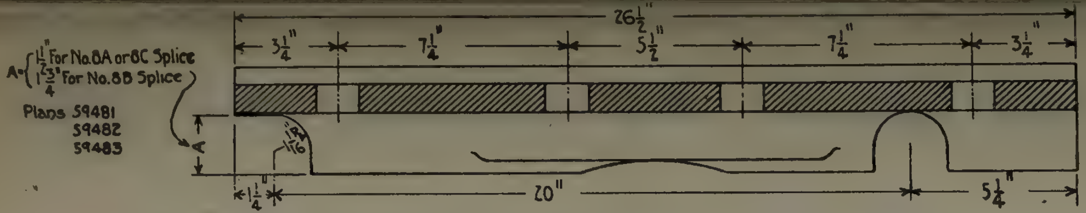
Rolled plate, 7 in. by 9 in. by 7/16 in.............0.397 in.
Cast plate, 7 in. by 13 in. by 15/16 in.............0.204 in.
Rolled plate, 7 in. by 13½ in. by ⅝ in.............0.217 in.

From these figures it is probably uneconomical to use the larger plates, but possibly further experimentation with better designed plates will justify the use of plates of about 100 sq. in. under heavy traffic on sharp curves. For the present we do not recommend a greater increase than the 1 in. recently added to the length of our standard tie-plate, making it 7 in. by 10¾ in., which we consider sufficient for the majority of our traffic.

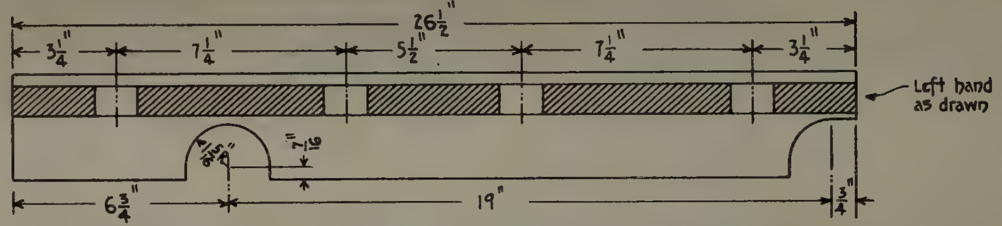
As to the thickness of the proposed plate, we are satisfied that ⅝ in. is sufficient thickness for a plate 10¾ in. long, from the fact above stated that no tendency to bend has been found in the 7½ in. by 9¾ in. by 9/16 in. plates rolled last year, and the fact stated in Mr. Zollinger's letter to you of July 24, 1913, that of 3,500 tie-plates 7 in. by 13½ in. by ⅝ in. only 17 were found bent, and these all under low rail of curve on chestnut ties, having carried our heaviest traffic four years.

We will advise you from time to time as to the progress of these experiments.

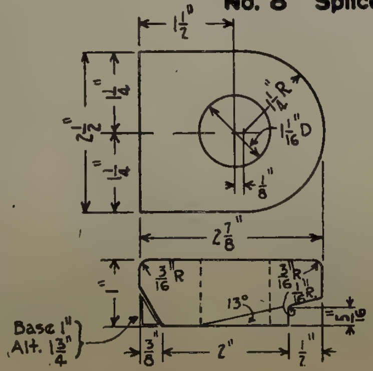
(Signed) W. G. Coughlin,
Engineer M. W.



SLOTTING OF SPLICE BARS FOR TYPES 8, 13 AND 14



SLOTTING OF SPLICE BARS FOR TYPES 9, 10, 11 AND 12
No. 8 Splice Bar Plan 59480 (Right and Left Hand)



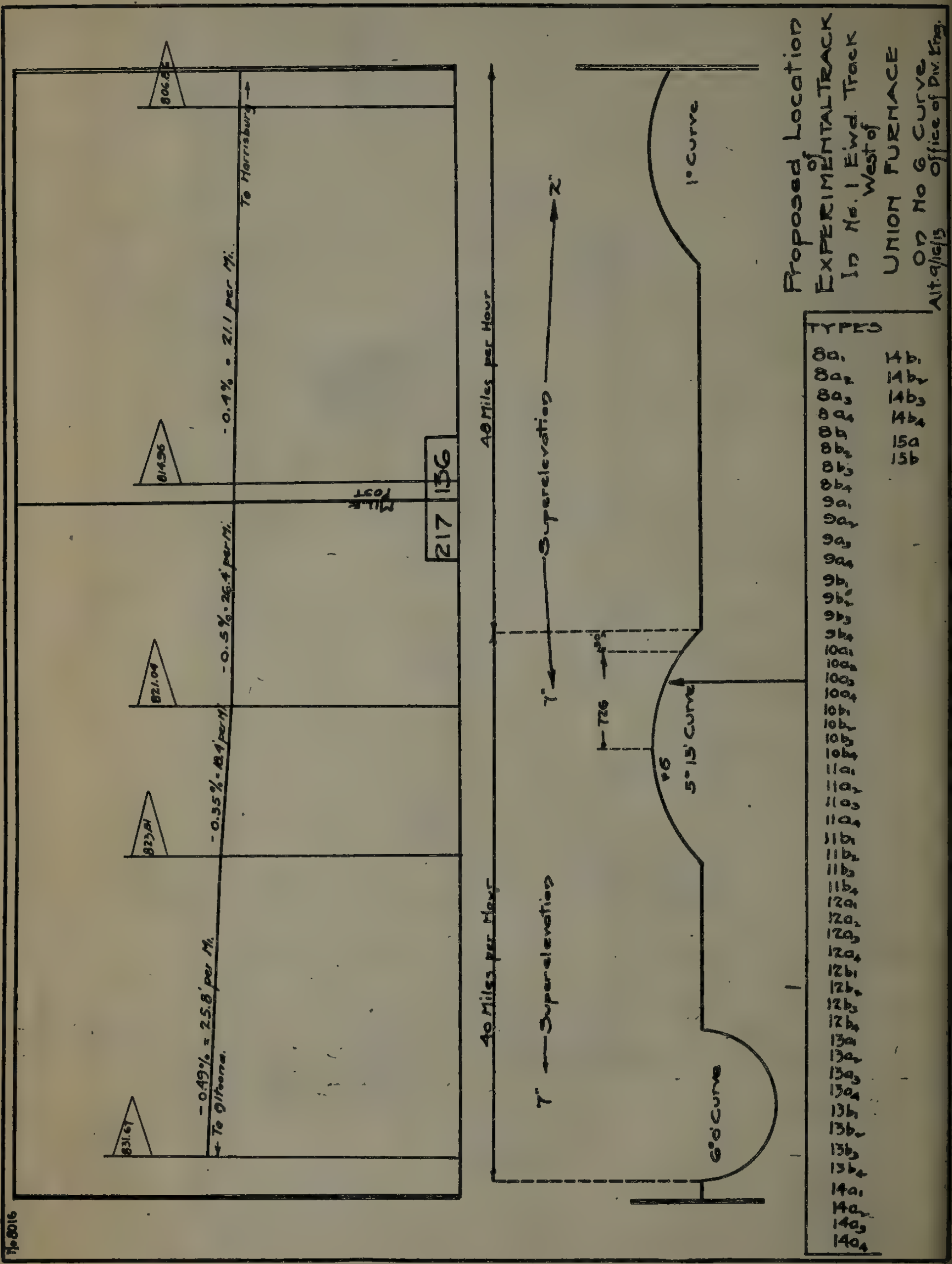
CLIP
FOR TYPES 9, 10, 11 AND 12

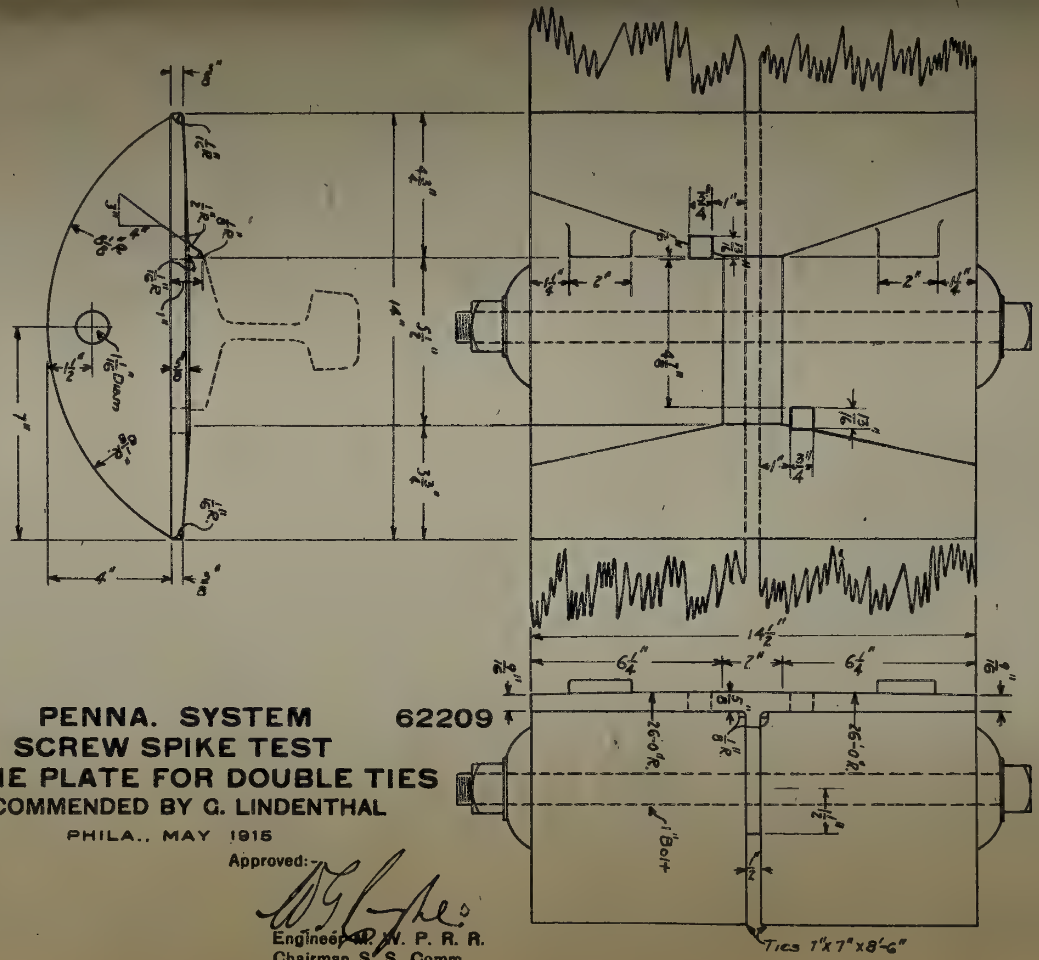
62184

PENNA SYSTEM
SCREW SPIKE TEST
CLIP AND SLOTTING OF SPLICE-BARS
TYPES 8 TO 14
PHILA APRIL 1915

Approved

Engineer M. W. P. R. R.
Chairman S. S. Comm.


Proposed Location
of
EXPERIMENTAL TRACK
In No. 1 Ewd. Track
West of
UNION FURNACE
on No 6 Curve.
Office of Div. Eng.
Alt. 9/16/13
TYPES
8a1 8a2 8a3 8a4 8b1 8b2 8b3 8b4
9a1 9a2 9a3 9a4 9b1 9b2 9b3 9b4
10a1 10a2 10a3 10a4 10b1 10b2 10b3 10b4
11a1 11a2 11a3 11a4 11b1 11b2 11b3 11b4
12a1 12a2 12a3 12a4 12b1 12b2 12b3 12b4
13a1 13a2 13a3 13a4 13b1 13b2 13b3 13b4
14a1 14a2 14a3 14a4
14b1 14b2 14b3 14b4
15a 15b
806.3
814.36
821.04
823.81
831.67
To Harrisburg
-0.4% = 21.1' per Mi.
-0.5% = 26.4' per Mi.
-0.35% = 18.4' per Mi.
-0.49% = 25.8' per Mi.
To Altoona
Mile Post
217 136
40 Miles per Hour
40 Miles per Hour
Superelevation
2"
7"
Superelevation
7"
1° Curve
5° 15' Curve
726
30'
6°0' Curve
No 8016



PENNA. SYSTEM 62209
SCREW SPIKE TEST
"T" TIE PLATE FOR DOUBLE TIES
RECOMMENDED BY G. LINDENTHAL

PHILA., MAY 1915

Approved:—

Engineer M. W. P. R. R.
Chairman S. S. Comm.

May 22, 1915.

Mr. W. G. Coughlin,
Engineer Maintenance of Way.

Dear Sir:

As directed by your letter of September 28, 1914, we have, after considerable delay, on May 11 installed the special tie-plates and spikes for experimental purposes, studies 4 and 5. Plates are located between M. P. 218 plus 4319, and M. P. 218 plus 4505 on No. 10 curve in No. 1 track, just east of L. J. Bridge No. 10, with white oak ties under 125-lb. rail, on a 5 deg. and 45 min. curve.

We attach a statement showing the unit costs of the work.

Yours truly,
(Signed) G. W. Creighton,
General Superintendent.

UNIT COSTS OF INSTALLATION OF EXPERIMENTAL TIE-PLATES AND SPIKES.

Installed May 11, 1915. Study No. 5, Screw-Spikes.

	Total Cost	*Unit Cost*
Tie-plates, 100 installed	$362.00	$3.62
Screw-spikes, Special 7¼ in., 200 installed	44.00	0.22
Screw-spikes, Exp. Standard 6¼ in., 200 installed	11.00	0.055
Labor removing old plates and plug holes	4.14	0.083 per tie
Labor boring holes	8.80	0.176
Labor distributing material, work train	.63	.....
Applying fastenings	11.55	0.231

Totals:—Rail fastenings 417.00
Applying fastenings 25.12
First lining and surfacing .... 5.99—$448.11

$8.96 per tie, $5.43 per foot of track, $28,670 per mile of track, exclusive of rail, ballast and cross-ties.

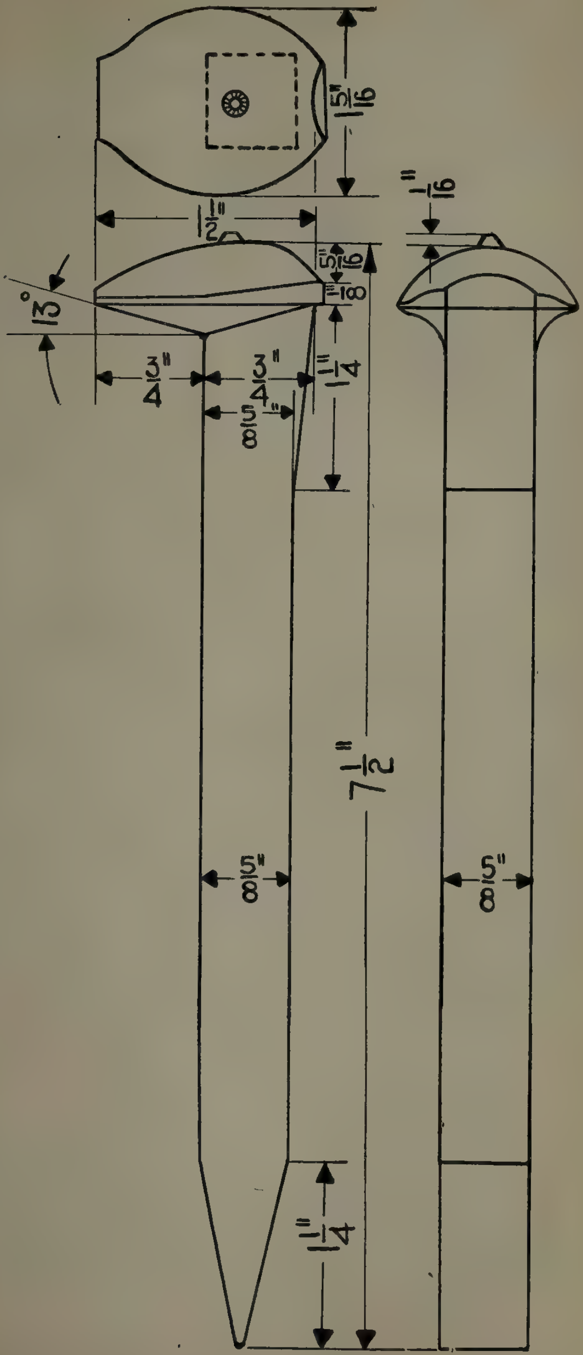
Installed May 11, 1915. Study No. 4, Driven Spikes.

	Total Cost	*Unit Cost*
Tie-plates, P. S. 125-lb., 100 installed	$362.00	$3.62
Spikes, Special 7½ in., 200 used	3.80	0.019
Spikes, Standard 6 in., 200 used	2.21	0.011
Labor removing old plates and plug holes	4.12	0.082 per tie
Labor applying fastenings	8.63	0.175

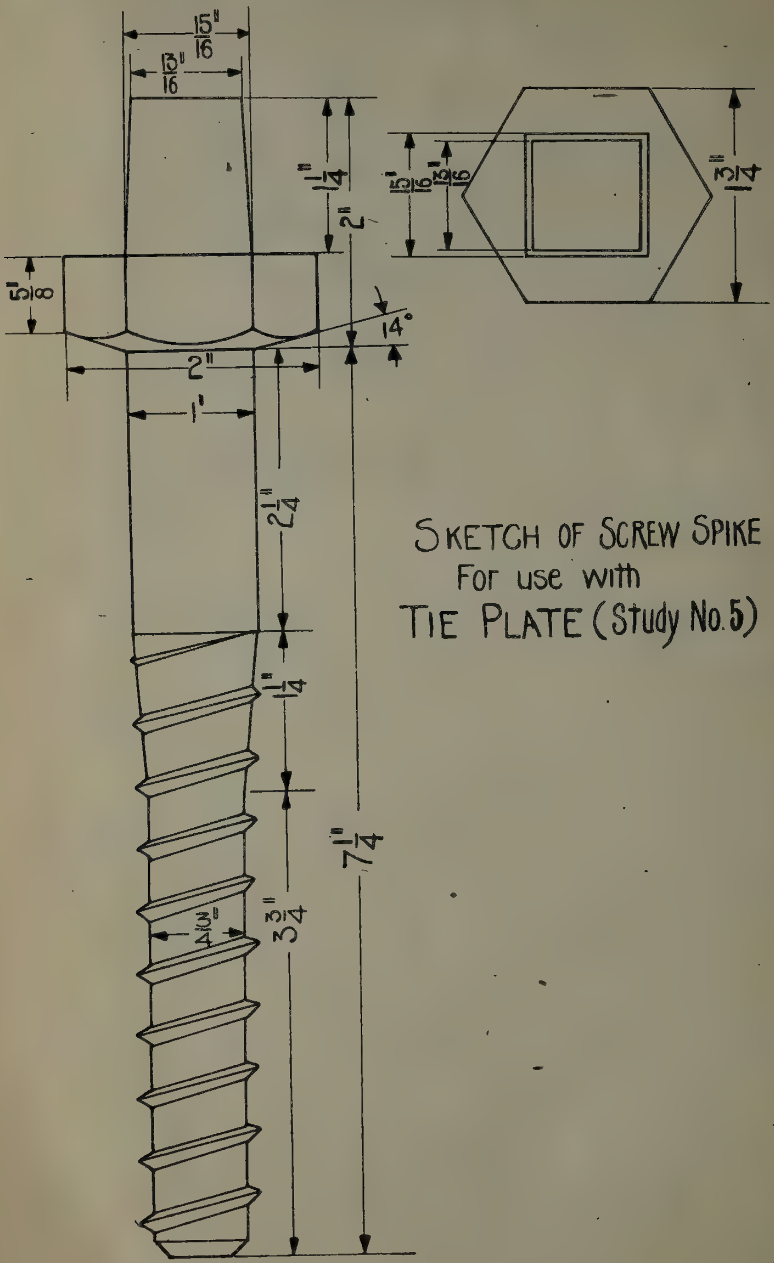
Totals:—Rail fastenings 368.01
Applying fastenings 12.75
Labor, first lining and surfacing .... 13.15—$393.91

$7.87 per tie, $4.77 per foot of track, or $25,186 per mile of track, exclusive of rail, ballast and cross-ties.

Altoona, Pa.
May 20, 1915.



Sketch of Spike for Use With Tie-Plate. (Study No. 4.)



SKETCH OF SCREW SPIKE
For use with
TIE PLATE (Study No. 5)

Philadelphia, April 30, 1915.

Mr. W. G. Coughlin,
Engineer Maintenance of Way.

Dear Sir:

I have noted your letter of the 27th instant to Mr. Creighton with interest, in reference to making repairs to the screw-spike track at Birmingham on the Middle Division. My only added suggestion would be that before plugging the holes they should be filled with creosote oil, so as to keep the screws in good condition.

I also think the screw-spikes have not sufficient holding power on the wood. My opinion is that no screw-spike of any size, the under side of the head of which is brought closely in contact with the base of rail, will remain in good condition for a considerable length of time. The under side of head should be not less than one-eighth of an inch from touching the base of rail, otherwise the movement of the rail on the ties will naturally either loosen the spikes or raise or lower the cross-ties as the rolling stock passes over same. In other words, I claim that the fundamental principle of the screw-spike, as applied in the tests now being made at Birmingham, is incorrect and you can expect unsatisfactory results.

Respectfully,
(Signed) A. C. Shand,
Chief Engineer.

May 24, 1915.

Mr. A. C. Shand,
Chief Engineer.

Dear Sir:

Referring to your letter of April 30th relative to Screw-Spike track at Birmingham, particularly the criticism that "no screw-spike of any size, the under side of the head of which is brought closely in contact with the base of rail, will remain in good condtition for a considerable length of time." * * * "In other words * * * the fundamental principle of the screw-spike as applied in the tests now being made at Birmingham is incorrect," we beg to advise that this principle was not ignored in arranging the screw-spike tests.

We have from the beginning advocated a space between the rail and screw-spike, and as you will notice from attached sketches a space of 3/32″ was provided in the design of the New York Tunnel tie-plate (Type 7 S. 3. Exp.) and this clearance was in later studies increased to ⅛″.

The members of the Screw-Spike Committee were not all in accord with this view, hence types 3, 4 and 6 were designed without this feature.

We enclose copy of letter from Mr. Hatch on this subject.

Yours truly
W. G. Coughlin,
Chairman, Committee on Screw-Spike Test.

VANDALIA RAILROAD COMPANY

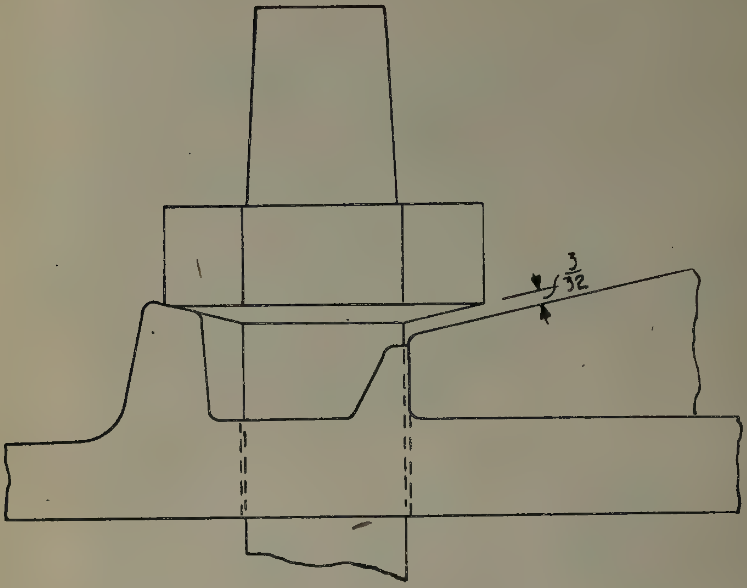
St. Louis, Mo., May 6, 1915.

Mr. W. G. Coughlin,
Chairman, Committee on Screw-Spike Test.

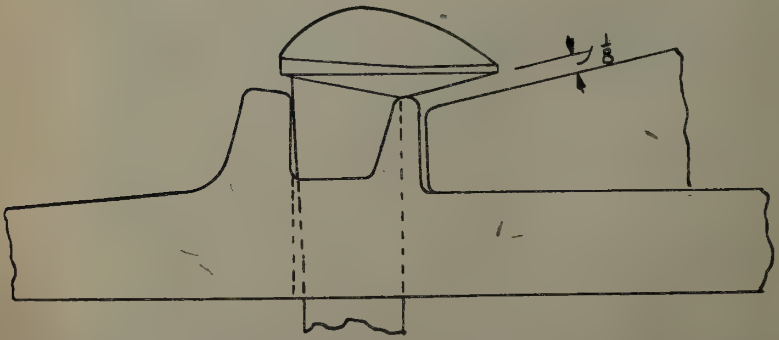
Dear Sir:

I have your favor of May 3rd, enclosing copy of a letter from Mr. Shand concerning proposed repairs to Type 7, Screw-Spike Track, at Birmingham, Pa.

I quite agree with Mr. Shand in his comments on the screw-spike. The screw-spike must not be screwed down tight against the base of



N Y Tunnel Tie Plate with Screw Spike



Study No. 3 (Accompanying letter of L. R. C. to S. C. L., 7-24-13).

the rail if good results are expected. The constant working of the spike in the wood will destroy the fibers so there will be no holding power whatever.

With the ordinary track spike the working of the rail under the traffic will tend to pull the spike out of the wood to a certain extent, but this does not hurt the fiber of the wood and the spike can be driven back again.

With a screw-spike working under the traffic in the same way the fiber of the wood next to the spike would be destroyed and nothing would remain to hold the spike when you attempt to screw it back again into place. For that reason there should be sufficient space between the head of the screw-spike and the base of the rail to allow for play of the rail without affecting the spike.

Yours truly,
(Signed) F. T. Hatch,
Chief Engineer.

PROPORTION OF LOAD ON RAIL TRANSMITTED TO EACH TIE.

Discussion of C. D. Young's report of 24th February, 1915 (p. 193).

Pittsburgh, Pa., April 29, 1915.

Mr. W. G. Coughlin, Chairman,
Committee on Screw-Spike Test.

Dear Sir:

At the meeting of the Committee in Altoona, September 3, 1914, it was arranged to have the Pennsylvania Railroad Test Department determine two things:

(1) The dynamic load sustained by a tie-plate in the track under traffic, and

(2) The intensity of pressure, or load per square inch, which can be sustained by a white oak tie under repeated applications of the load, without destruction of the fibers of the wood.

Your letter of March 9, 1915, informs us that the first portion of the plan has been carried out, and you have furnished us with a complete copy of the report, No. 15-12, dated February 24, 1915, by Mr. Young to Mr. Wallis, and in it Mr. Young recommends, in the last paragraph, that it be referred to the Committee on Screw-Spike Test, to advise what load they desire to have used for the laboratory investigation of the ties and tie-plates. On this question, I offer the following comments:

I find myself at present quite in accord with Mr. Young's conclusions in paragraph 29, on page 163, as follows:

"(a) The design of tie-plates to meet curve conditions should be different from that on tangent track, due to the fact that the variation in the elevation of the curve has a material bearing upon the load which the tie-plate sustains, and as this elevation can only be made for a compromise speed, excessive loads will occur at other speeds.

"(b) Tie-plates designed for use on curves up to and including 2 degrees might be of the same class as those designed for tangent track.

"(c) The bearing value of tie-plates for curves of 6 degrees and over should be approximately twice that used on tangent track.

"(d) Tie-plates for curves of between 2 and 6 degrees in all probability do not need as great a bearing value as tie-plates used on 6-degree curves and over, but should have a bearing value greater than tie-plates on tangent track.

"(e) It would therefore seem that, in order not to have too many designs of tie-plates, the dividing line for change in design from tangent to curved track would be between the 2-degree and 6-degree curve, and that the bearing value of the two designs of tie-plates should be approximately 1.6 to 1 in."

These deductions correspond with experience, and the speed up to which the results on tangent and curved track correspond fairly well, viz., 40 miles per hour, as mentioned by Mr. Young in a portion of the report, is also significant. It is in the neighborhood of this speed, viz., about 45 miles per hour, when 8 inches is fixed by experience as the practicable limit of superelevation for the outer rail on curves, which is the limit for 6-degree curves. Also, on the 3-degree-thirty-minute curve, 8 inches is the superelevation required for a speed of 60 miles per hour. As a practicable limit, the Transportation Department has fixed upon a limitation of speed of about 40 to 45 miles per hour around curves, from 4 degrees to 6 degrees, having standard superelevation, while there has been a great deal of discussion about limiting the speed to 60 miles per hour on all curves less than 4 degrees, having standard superelevation, and that is practically the rule at the present time on the Lines West of Pittsburgh.

From these conditions, therefore, I would place the figure which Mr. Young does not name, but which he considers between 2 degrees and 6 degrees, at 3-degree-30-minute curves, up to and including which the tie-plate designed for tangent track should be used, and a special tie-plate for curved track over 3 degrees 30 minutes.

From these tests he fixes the required bearing area of the tie-plate for the sharp curves, i. e., for the curves over the figure which I fixed above at 3 degrees 30 minutes, at 60 per cent. greater than the bearing area of the tie-plate required for tangent track and up to 3-degree-30-minute curves. I have no criticism of this to make at present.

On page 164 he recommends that the tie-plate for tangent track be designed to sustain a load of not less than 38,000 lbs., and this is approximately the figure which I worked out from Mr. Young's preliminary tests of some time ago. I am rather inclined to agree with his reasoning, and recommend that that be the figure which we use for making the tests to determine the intensity of pressure which can be successfully sustained by the oak ties, supposing them to be laid on tangent track and curved track up to 3 degrees 30 minutes.

Accepting also the reasoning of the necessity for a special tie-plate for curved track of over 3 degrees 30 minutes, it will be necessary to carry on tests to determine the bearing area of the tie-plate necessary to keep the intensity of pressure on the wood the same as in the case of the tie on tangent track and curves up to 3 degrees 30 minutes, because the load to be provided for in this case will be 60 per cent. greater, or not less than 60,000 lbs., as stated by Mr. Young, paragraph 34.

Inasmuch as the tests to determine the intensity of pressure which white oak ties will successfully sustain will be laboratory tests under static conditions, it appears that it will be necessary to use static loads greater than the 38,000 and the 60,000 lbs. of dynamic load mentioned above, in order to produce the same effect, and Mr. Young has therefore studied the relation between the effects of the static and dynamic loads and determines that the ratio of the static load to the dynamic load was not to exceed 1 to 1.20 for tangent track, i. e., the static load, to produce the same effect as the dynamic load, should be about 20 per cent. greater than 38,000 lbs., or, say, approximately 45,000 lbs., while for the track of sharp curvature it should be about twice as great, or 120,000 lbs.

I recommend, therefore, in answer to your letter, that the loads used in the laboratory experiments be 45,000 lbs. for tangent and curved track up to 3 degrees 30 minutes, and 120,000 lbs. for curved track over 3 degrees 30 minutes.

I also recommend that we do not proceed with the installation of additional sizes of tie-plates in the track until we have studied the results of the additional experiments which are to be made by the Test Department.

It is also apparent from these tests that, on Divisions where the smaller and lighter locomotives are used, like the D-16 class, a still smaller tie-plate can be provided. The requirements seem to be for a load of about 22,000 lbs. for tangent and curved track up to 3 degrees 30 minutes, with a 60 per cent. increase for curvature over 3 degrees 30 minutes, and it seems possible to draw up a set of rules for the use of tie-plates in accordance with the weight of the equipment and the density of the traffic.

Yours truly,
(Signed) W. C. Cushing,
Chief Engineer Maintenance of Way.

BULLETIN

OF THE

American Railway Engineering Association

Vol. 19, No. 201 . . . . NOVEMBER, 1917

CONTENTS

Report on Signals and Interlocking

Charles Lee Crandall

A Memoir

W. D. PENCE, *Editor*,
Chicago, Ill.

E. H. FRITCH, *Secretary*,
910 Michigan Avenue,
Chicago, Ill.

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Special Committee on Manual.

Chas. S. Churchill, Chairman; W. B. Storey, Edwin F. Wendt, Robert Trimble, A. S. Baldwin.

Committee on Membership.

C. F. W. Felt, Chairman; R. N. Begien, E. H. Fritch.

NOMINATING COMMITTEE

Chas. S. Churchill (*Senior Past-President—Chairman*), Assistant to President, Norfolk & Western Railway, Roanoke, Va.

Edwin F. Wendt (*Past-President*), Member Engineering Board, Division of Valuation, Interstate Commerce Commission, Washington, D. C.

W. B. Storey (*Past-President*), Vice-President, Atchison, Topeka & Santa Fe Railway System, Chicago, Ill.

Robert Trimble (*Past-President*), Chief Engineer Maintenance of Way, Northwest System, Pennsylvania Lines, Pittsburgh, Pa.

A. S. Baldwin (*Past-President*), Chief Engineer, Illinois Central Railroad, Chicago, Ill.

J. R. W. Ambrose, Chief Engineer, Toronto Terminals Railway, Toronto, Ont., Canada.

Geo. H. Burgess, Chairman, Valuation Committee, Delaware & Hudson Company, Albany, N. Y.

W. M. Dawley, Assistant Engineer, Erie Railroad, New York City.

V. K. Hendricks, Assistant Chief Engineer, St. Louis-San Francisco Railroad, St. Louis, Mo.

S. T. Wagner, Chief Engineer, Philadelphia & Reading Railway, Philadelphia, Pa.

American Railway Engineering Association

VOL. 19, No. 201 . . . . NOVEMBER, 1917

FOREWORD.

Beginning with the November number, the Bulletins to be issued prior to the ensuing convention will contain Committee reports to be acted on at the annual convention in March next.

In order to make the meetings of the annual convention interesting and profitable, it is essential to have full and free discussion of the Committee reports on the floor, which will bring about corrections and improvements, if required, and at the same time furnish additional information from the experiences of the speaker or writer.

That the discussions may be such as to accomplish the above result, it is advisable that each member study the reports carefully as soon as issued in the Bulletin, and prepare in advance the data and information which he desires to give to the Association while taking part in the debate.

Members who may be unable for special reasons to attend the annual convention are requested to send to the Secretary written discussions of such reports in which they are particularly interested.

Members are requested to bring their Bulletins containing committee reports to the convention, as the supply of extra copies is limited. Additional copies will be furnished to members during the convention at cost.

JOHN G. SULLIVAN,
President.

REPORT OF COMMITTEE X—ON SIGNALS AND INTERLOCKING.

J. A. Peabody, *Chairman;*	W. J. Eck, *Vice-Chairman;*
Azel Ames,	J. G. M. Leisenring,
C. C. Anthony,	H. K. Lowry,
H. S. Balliet,	J. C. Mock,
A. M. Burt,	F. P. Patenall,
C. A. Christofferson,	A. H. Rudd,
C. E. Denney,	W. B. Scott,
F. L. Dodgson,	A. G. Shaver,
C. A. Dunham,	T. S. Stevens,
W. H. Elliott,	W. M. Vandersluis,
G. E. Ellis,	B. Wheelwright,
M. H. Hovey,	

Committee.

To the American Railway Engineering Association:

Your Committee presents herewith its annual report for the year 1917.

The following subjects were assigned to your Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on the problem of signaling single-track roads with reference to the effect of signaling and proper location of passing sidings on the capacity of the line.

3. Report on specifications adopted by the Railway Signal Association, which, in the judgment of the Committee, warrant consideration, conferring with Committee on Track on any appliances affecting track.

4. Report on the desirability of having an overlap in automatic signaling; if so, is it best to have two stop indications between trains or two caution indications instead, or the latter in special cases only, such as down-grade tracks?

5. Report on the various methods of giving signal indications other than by means of the semaphore (this includes the light signal for day and night indications).

6. Report on the feasibility of separating into distinct types of their own (a) the signals for train operation, and (b) the markers or signs which indicate the location or position, or both, of information signs and switch signals for conveying information to trainmen.

   (a) The semaphore is now almost universally used for governing train operation, therefore

   (b) Design suitable day and night (if necessary) markers or signs for switch signals, derail switches, stop posts, slow posts, resume speed posts, water station and track-pan markers, highway crossing signals, etc., conferring with Committee on Signs, Fences and Crossings.

7. Report on requisites of signal locations for interlocking and block signals.

8. Report on automatic train control.

9. Report on the comparative merits in various locations of alternating current and direct current for operation of automatic signals.

10. Report on applications of aspect for instructions to trains to take siding at a non-interlocked switch.

COMMITTEE MEETINGS.

Four meetings of the whole Committee were held during the year, two being held in Buffalo and two in Chicago, besides which a number of meetings were held by sub-committees.

(1) REVISION OF MANUAL.

In Appendix A your Committee submits revisions of five plates of symbols, now included in the Manual.

(2) REPORT ON THE PROBLEM OF SIGNALING SINGLE-TRACK ROADS WITH REFERENCE TO THE EFFECT OF SIGNALING AND PROPER LOCATION OF PASSING SIDINGS ON THE CAPACITY OF THE LINE.

In last year's report your Committee stated that "Our work on this subject will be in applying and testing the formulas or methods on pieces of roads with their actual movements of trains." Considerable work along this line has been done and your Committee reports progress.

(3) REPORT ON SPECIFICATIONS ADOPTED BY THE RAILWAY SIGNAL ASSOCIATION.

In Appendix B your Committee submits a list of matters acted on by the Railway Signal Association at its convention in 1917 and adopted by letter-ballot. The recommendations of your Committee on this subject are given under the heading of Conclusions.

(4) REPORT ON THE DESIRABILITY OF HAVING AN OVERLAP IN AUTOMATIC SIGNALING; IF SO, IS IT BEST TO HAVE TWO STOP INDICATIONS BETWEEN TRAINS OR TWO CAUTION INDICATIONS INSTEAD, OR THE LATTER IN SPECIAL CASES ONLY, SUCH AS DOWN-GRADE TRACKS?

Sub-Committee assigned this subject has done some work and your Committee reports progress.

(5) REPORT ON THE VARIOUS METHODS OF GIVING SIGNAL INDICATIONS OTHER THAN BY MEANS OF THE SEMAPHORE (THIS INCLUDES THE LIGHT SIGNAL FOR DAY AND NIGHT INDICATIONS).

No work has been done on this subject during the year.

(6) REPORT ON THE FEASIBILITY OF SEPARATING INTO DISTINCT TYPES OF THEIR OWN THE SIGNALS FOR TRAIN OPERATION AND THE MARKER OR SIGNS WHICH INDICATE THE LOCATION OR POSITION, OR BOTH, OF INFORMATION SIGNS AND SWITCH SIGNALS FOR CONVEYING INFORMATION TO TRAINMEN.

In Appendix C your Committee makes report on this topic and its recommendations are given under the head of Conclusions.

(7) REPORT ON REQUISITES OF SIGNAL LOCATIONS FOR INTERLOCKING AND BLOCK SIGNALS.

No progress made.

(8) REPORT ON AUTOMATIC TRAIN CONTROL.

There having been no new developments during the year in automatic train control devices, the Committee has nothing to report.

(9) REPORT ON THE COMPARATIVE MERITS IN VARIOUS LOCATIONS OF ALTERNATING CURRENT AND DIRECT CURRENT FOR OPERATION OF AUTOMATIC SIGNALS.

In considering the merits in various locations of alternating current and direct current for operation of automatic signals, it was agreed that the comparative values of the two systems depend entirely upon local conditions.

Your Committee recommends that this subject be discontinued.

(10) REPORT ON APPLICATIONS OF ASPECT FOR INSTRUCTIONS TO TRAINS TO TAKE SIDING AT A NON-INTERLOCKED SWITCH.

On this subject your Committee reports progress.

CONCLUSIONS.

Your Committee recommends that the following action be taken on the report submitted herewith:

1. In connection with subject, "Make critical examination of subject-matter in Manual," that the five plates of symbols, the first four of which are revisions of those now shown on pages 413, 414, 415, and 421 of the Manual, and the fifth a new one, be adopted and inserted in the Manual in place of those now shown.

3. That the submitted list of Railway Signal Association specifications and standards be published in the Manual, as supplementary to list heretofore inserted, for information of the members.

6. That the designs submitted be adopted and included in the Manual.

9. That the subject of Comparative Merits in Various Locations of Alternating Current and Direct Current for Operation of Automatic Signals be discontinued.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

Your Committee considers that no further work can be done on Subject No. 9 and recommends that same be considered closed.

Your Committee further recommends that the following subjects be continued:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

2. Report on the problem of signaling single-track roads with reference to the effect of signaling and proper locations of passing sidings on the capacity of the line.

3. Report on the specifications adopted by the Railway Signal Association, which, in the judgment of the Committee, warrant consideration, conferring with Committee on Track on any appliances affecting track.

4. Report on the desirability of providing in connection with an automatic signal system:
   - (a) An overlap.
   - (b) Approach restricting speed indications.

5. Report on the various types of light signals for day and night indications.

6. Report on the feasibility of separating into distinct types of their own, the signals for train operation, and the markers or signs which indicate the locations or position, or both, of information signs and switch signs for conveying information to trainmen, and design suitable day and night (if necessary) markers or signs for switches, derailing switches, stop signs, slow signs, resume speed signs, water station and track pan markers, highway crossing signs, etc.

7. Report on requisites of signal locations for automatic block signals for single-track roads.

8. Report on Automatic Train Control.

10. Report on applications of aspect indicating that train must take siding at a non-interlocked switch.

Respectfully submitted,

The Committee on Signals and Interlocking.

Appendix A.

(1) REVISION OF MANUAL.

J. A. Peabody, Chairman, Sub-Committee.

Your Committee submits the following five plates of symbols, these in accordance with revisions made and adopted by the Railway Signal Association:

First Plate (R. S. A. Plate No. 4).

Revision of that shown at present on page 413 of the Manual, revisions being as follows:

Changes.

Take or leave siding indicator (new).
Battery chute, relay box and post combined (revised).
Battery shelter (revised).
Highway crossing signals (all new except bell).

Second Plate (R. S. A. Plate No. 5).

Revision of that shown at present on page 414 of the Manual, revisions being as follows:

Changes.

(Slight changes in titles.)
Three-throw switch, three illustrations (new).
Derails revised and added to (second note new).
Plunger lock (new).
Switch and lock movement (revised).
Facing point lock (revised).
Oil enclosed wire line (new).
Pipe adjusting screw (new).
Wire adjusting screw (new).
Note: Seven symbols under "Runs" transferred to Plate 5.

Third Plate (R. S. A. Plate No. 6).

Revision of that shown at present on page 415 of the Manual, revisions being as follows:

Changes.

Rocking shaft lead-out (revised). (Wire line shown dotted instead of solid.)

Added.

No. 9—Rigid Crossing Frog.

Fourth Plate (R. S. A. Plate No. 12).

Revision of that shown at present on page 421 of the Manual, revisions being as follows:

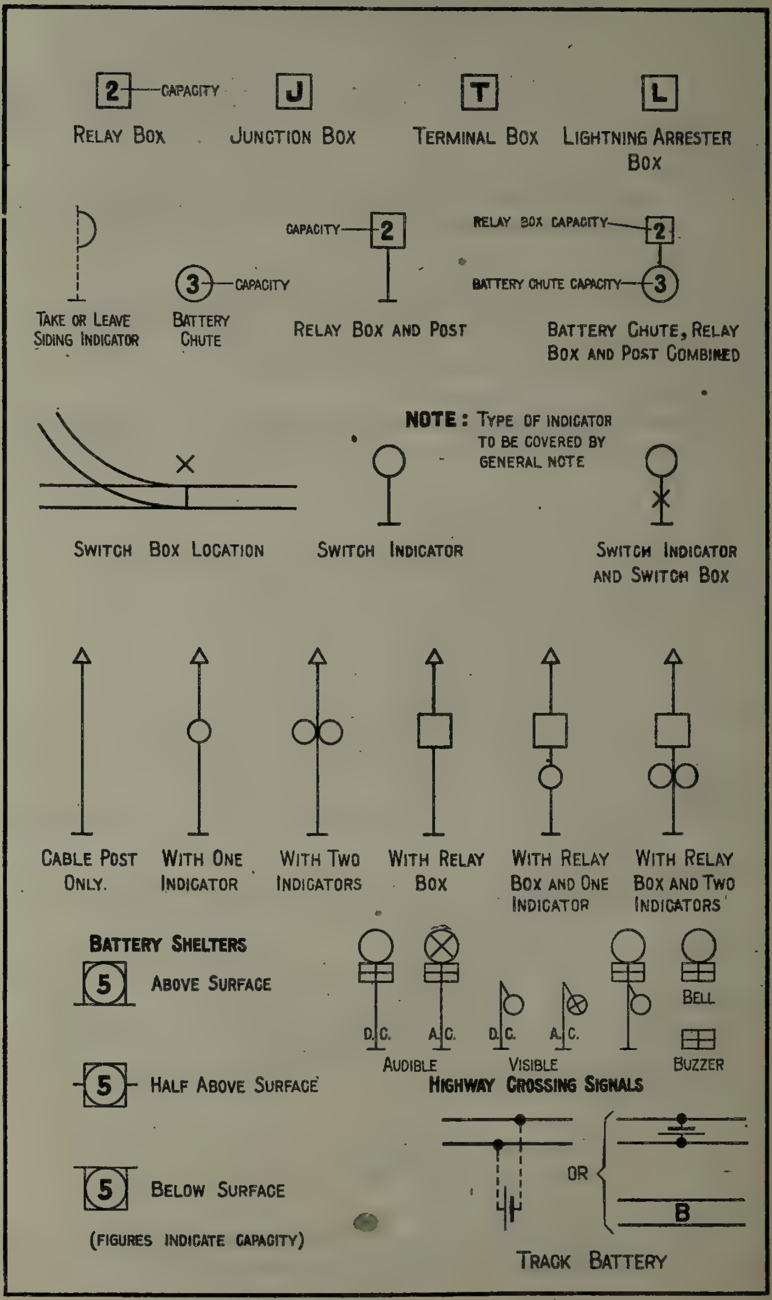
Changes.

Transformers:
  for grounding case (new).
  for grounding shield (new).

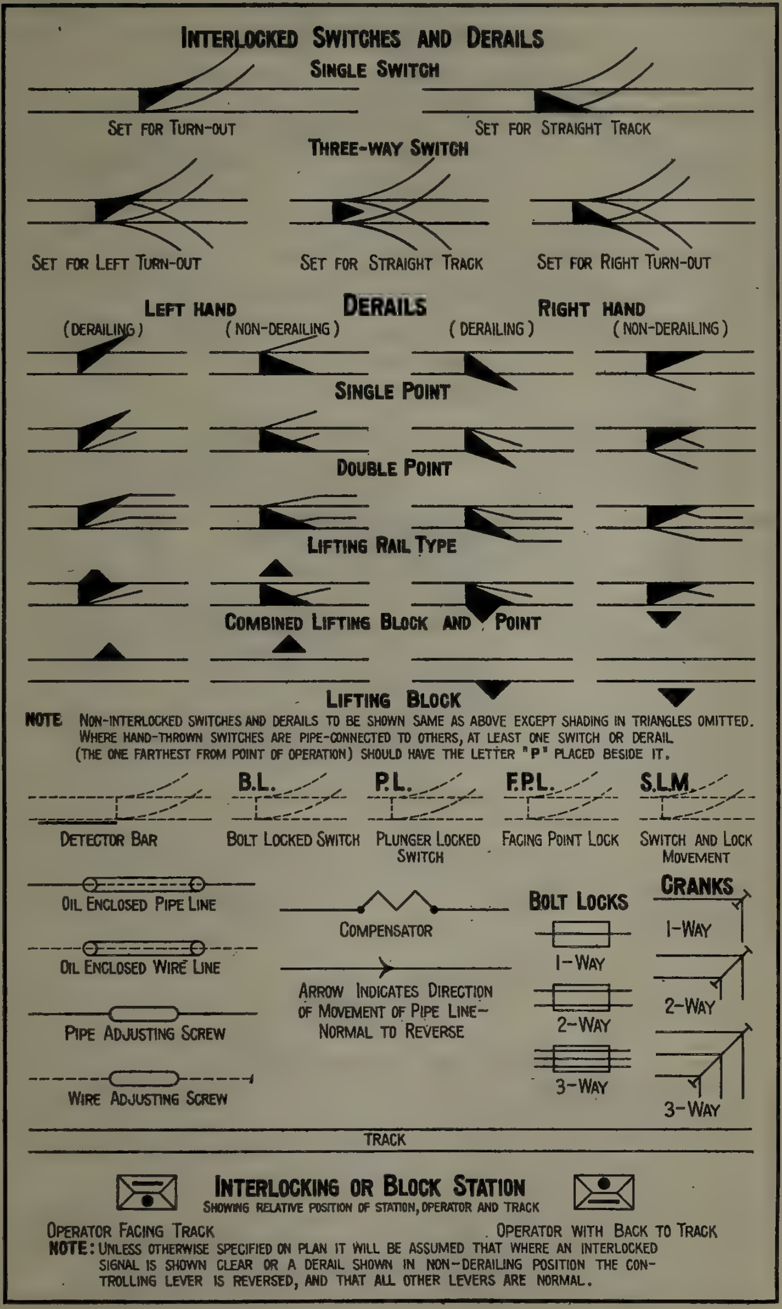
Fifth Plate (R. S. A. Plate No. 13).

This is new except runs of connections which were taken from plate at present shown on page 414 of the Manual.

PLATE NO. 4. R.S.A. SYMBOLS. OCT. 1911 – REVD. OCT. 1917



No 5 R.S.A. SYMBOLS. OCT. 1911 - REDRAWN, OCT. 1917 -



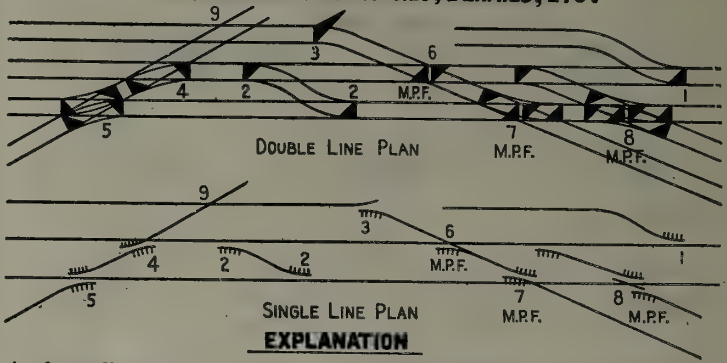
NOTE NON-INTERLOCKED SWITCHES AND DERAILS TO BE SHOWN SAME AS ABOVE EXCEPT SHADING IN TRIANGLES OMITTED. WHERE HAND-THROWN SWITCHES ARE PIPE-CONNECTED TO OTHERS, AT LEAST ONE SWITCH OR DERAIL (THE ONE FARTHEST FROM POINT OF OPERATION) SHOULD HAVE THE LETTER "P" PLACED BESIDE IT.

ARROW INDICATES DIRECTION OF MOVEMENT OF PIPE LINE—NORMAL TO REVERSE

NOTE: UNLESS OTHERWISE SPECIFIED ON PLAN IT WILL BE ASSUMED THAT WHERE AN INTERLOCKED SIGNAL IS SHOWN CLEAR OR A DERAIL SHOWN IN NON-DERAILING POSITION THE CONTROLLING LEVER IS REVERSED, AND THAT ALL OTHER LEVERS ARE NORMAL.

PLATE NO. 6. R. S. A. SYMBOLS. OCT. 1911—REVD. OCT. 1917

INTERLOCKED SWITCHES, DERAILS, ETC.



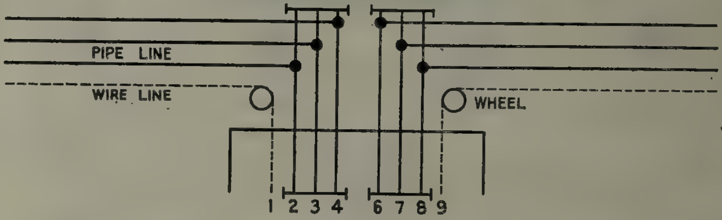
DOUBLE LINE PLAN

SINGLE LINE PLAN

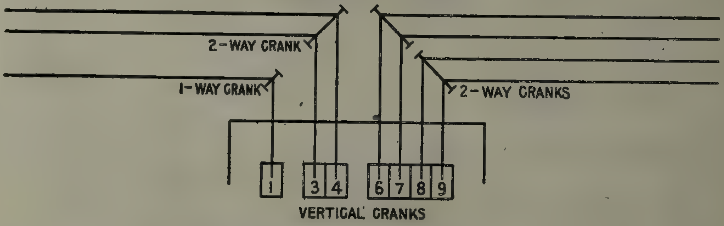
EXPLANATION

1 — SIMPLE TURN-OUT
2 — SIMPLE CROSS-OVER
3 — DERAIL—SINGLE POINT
4 — SINGLE SLIP SWITCH
5 — DOUBLE SLIP SWITCH
6 — MOVABLE POINT CROSSING FROG (M.P.F.)
7 — SINGLE SLIP SWITCH WITH M.P.F.
8 — DOUBLE SLIP SWITCH WITH M.P.F.
9 — RIGID CROSSING FROG

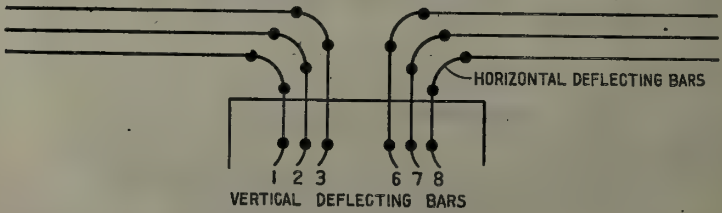
ROCKING SHAFT LEAD-OUT



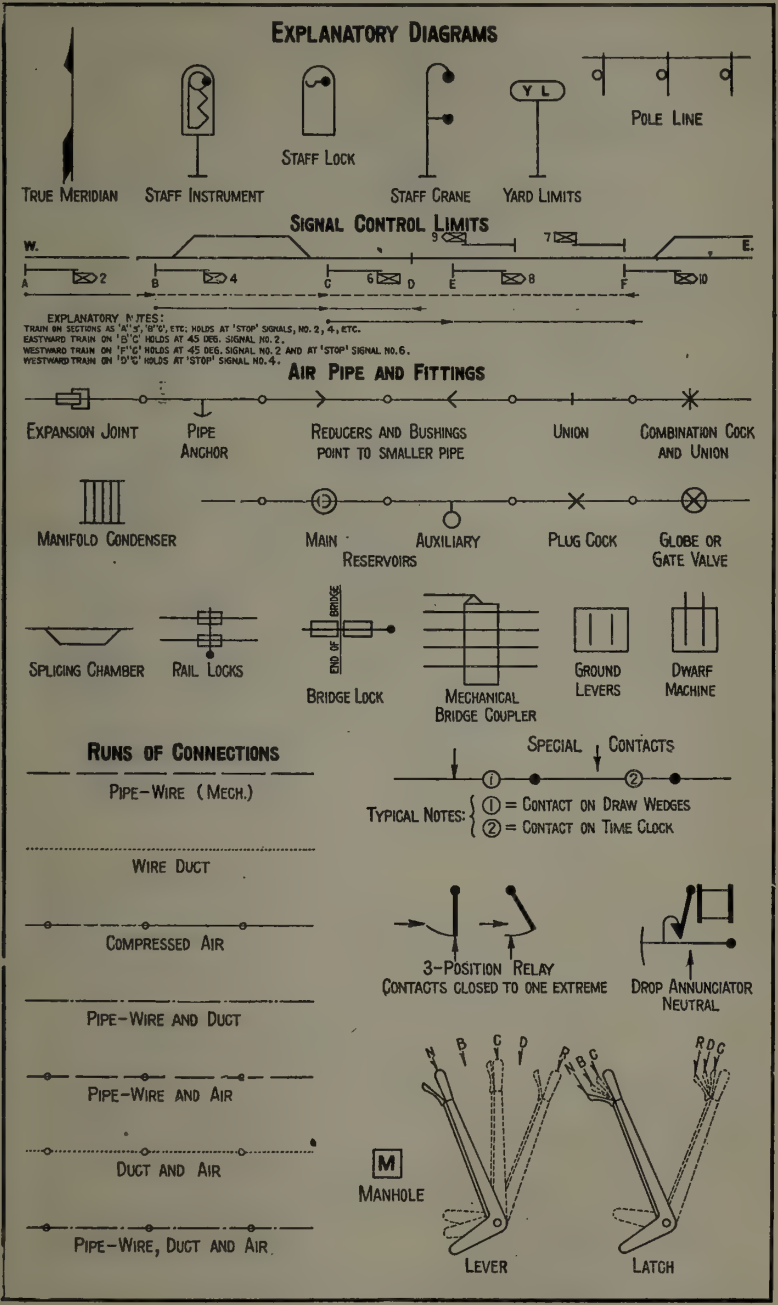
CRANK LEAD-OUT



DEFLECTING BAR LEAD-OUT



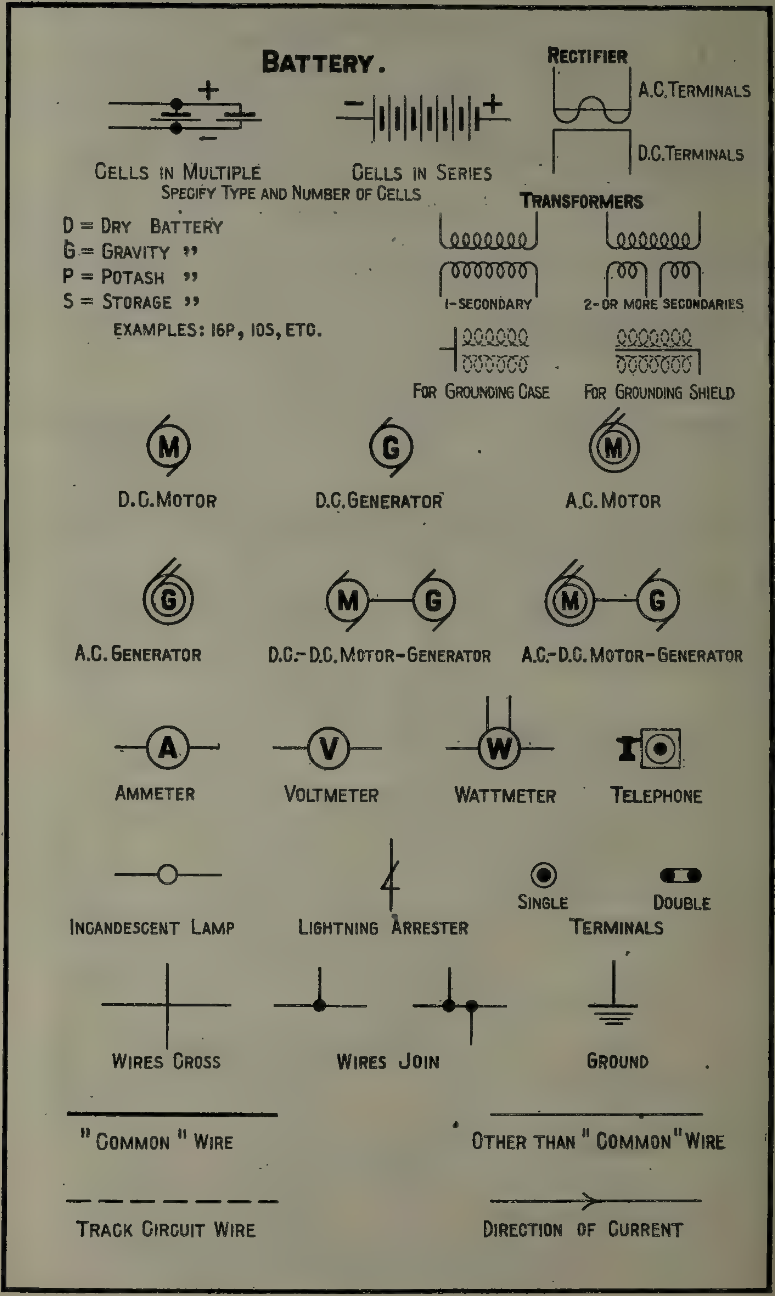
NO.13 R.S.A. SYMBOLS. OCT.1917–



EXPLANATORY NOTES:
TRAIN ON SECTIONS AS 'A''B', 'B''C', ETC; HOLDS AT 'STOP' SIGNALS, NO. 2, 4, ETC.
EASTWARD TRAIN ON 'B''C' HOLDS AT 45 DEG. SIGNAL NO. 2.
WESTWARD TRAIN ON 'F''C' HOLDS AT 45 DEG. SIGNAL NO. 2 AND AT 'STOP' SIGNAL NO. 6.
WESTWARD TRAIN ON 'D''C' HOLDS AT 'STOP' SIGNAL NO. 4.

TYPICAL NOTES: { ① = CONTACT ON DRAW WEDGES
② = CONTACT ON TIME CLOCK

PLATE NO. 12. R. S. A. SYMBOLS. OCT. 1911 - REVD. OCT. 1917



Appendix B.

(3) REPORT ON SPECIFICATIONS ADOPTED BY THE RAILWAY SIGNAL ASSOCIATION, WHICH, IN THE JUDGMENT OF THE COMMITTEE, WARRANT CONSIDERATION, CONFERRING WITH COMMITTEE ON TRACK ON ANY APPLIANCES AFFECTING TRACK.

J. A. PEABODY, Chairman, Sub-Committee.

Your Committee submits the following list of matters acted upon by the Railway Signal Association at its convention in 1917 and adopted by letter-ballot:

LIST OF FINDINGS, CONCLUSIONS, STANDARDS AND SPECIFICATIONS ADDED TO THE MANUAL BY THE RAILWAY SIGNAL ASSOCIATION IN 1917.

Text.

Alternator (Specifications).
Battery, Storage:
  Alkaline, Instructions for Maintenance of.
Electrical Instruments, D. C., Specifications for Ranges and Scales.
Ground Apparatus, Made, for Lightning Arresters (Specifications).
Hand Lantern Globes (Specifications).
Impedance Bond (Specifications).
Lightning Arresters, Made, Ground Apparatus for (Specifications).
Pipe Lines, Field Construction of.
Reactors, Air-cooled, for Line and Track Circuits (Specifications).
Resistors for Line and Track Circuits (Specifications).
Switchboard Material (General Specifications).
Switchboard Material (Requisite Sheets).
Transformers, Single-phase Line, Oil-immersed Self-cooled Outdoor type (Specifications).

Drawings.

Ballast and Rail Resistance Test Chart	RSA 6
Cable Post, Relay Box, Mountings	RSA 1374
Deflecting Bars	RSA 1069
Deflecting Stands, Horizontal Adjustable	RSA 1396
Electrical Instruments, Scale Ranges for	RSA 1378
Ground Resistance, Test for	RSA 1377
Hand Lantern Globes	RSA 1394
Lightning Arrester Grounds	RSA 1424
Rail Resistance Chart, Ballast and	RSA 6
Relay Boxes—Size "A" and "B"	RSA 1182
Relay Box—Size "A") (Details)	RSA 1184
Relay Box—Size "B" (Details)	RSA 1183
Relay Box and Cable Post Mountings	RSA 1374
Relay Box Fittings	RSA 1369
Relay Box Inlet Bracket	RSA 1367
Relay Box Linings and Terminal Boards	RSA 1368
Thermometer (Stationary Lead Type Storage Battery)	RSA 1375
Track Circuit Test Chart	RSA 4

Appendix C.

(6) REPORT ON THE FEASIBILITY OF SEPARATING INTO DISTINCT TYPES OF THEIR OWN (a) THE SIGNALS FOR TRAIN OPERATION, AND (b) THE MARKER OR SIGNS WHICH INDICATE THE LOCATION OR POSITION, OR BOTH, OF INFORMATION SIGNS AND SWITCH SIGNALS FOR CONVEYING INFORMATION TO TRAINMEN.

(a) The semaphore is now almost universally used for governing train operation, therefore,

(b) Design suitable day and night (if necessary) markers or signs for switch signals, derail switches, stop posts, slow posts, resume speed posts, water station and trackpan markers, highway crossing signals, etc., conferring with Committee on Signs, Fences, and Crossings.

A. M. Burt, Chairman, Sub-Committee.

In our investigation of this subject, we have developed the following:

Some of the so-called signs govern train operation just as much as the movable semaphore of an interlocking or block signal system, and these signs are recognized in the Standard Code of the American Railway Association as signals. See note to the definition of fixed signals, page 235, Rule Book of the American Railway Association, January, 1916, reading as follows:

"The definition of a 'Fixed Signal' covers such signals as slow boards, stop boards, yard limits, switch, train-order, block, interlocking, semaphore, disc, ball or other means for displaying indications that govern the movement of a train."

Under this definition stop boards, slow boards, etc., are in fact signals. We have confined our work to designing the signs that fall under the above definition and those that are closely related to them, namely, those that convey instructions to an engineman although they may not "govern the *movement* of a train."

As a guide to our work, inquiries were sent out to all railroads represented in the American Railway Engineering Association. Standard plans were received from forty-three roads and these were tabulated as to type, painting, etc.

We are submitting designs for the following signs:

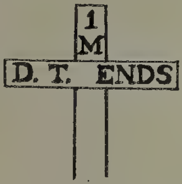
1. Stop.
2. Speed limit or Slow.
3. Resume speed.
4. Yard limit.
5. Station one mile.
6. Yard one mile.
7. Junction one mile.
8. Crossing one mile.

9. Draw one mile.
10. Highway Crossing Whistle Post.
11. Flanger sign.

We are not yet ready to report on the switch target, derail sign and trackpan sign, and there may be others, although most if not all of the other signs come under the general heading of information signs.

We recommend that all of the information signs such as trespass signs, section limits, right-of-way limits, city limits, end of double track, etc., be of such shape as not to conflict with the designs herewith submitted.

Where a preliminary sign not covered by the designs submitted is needed in the rear of an information sign, we recommend that it be made in the same form and general character as signs numbered 5 to 9, as indicated below:

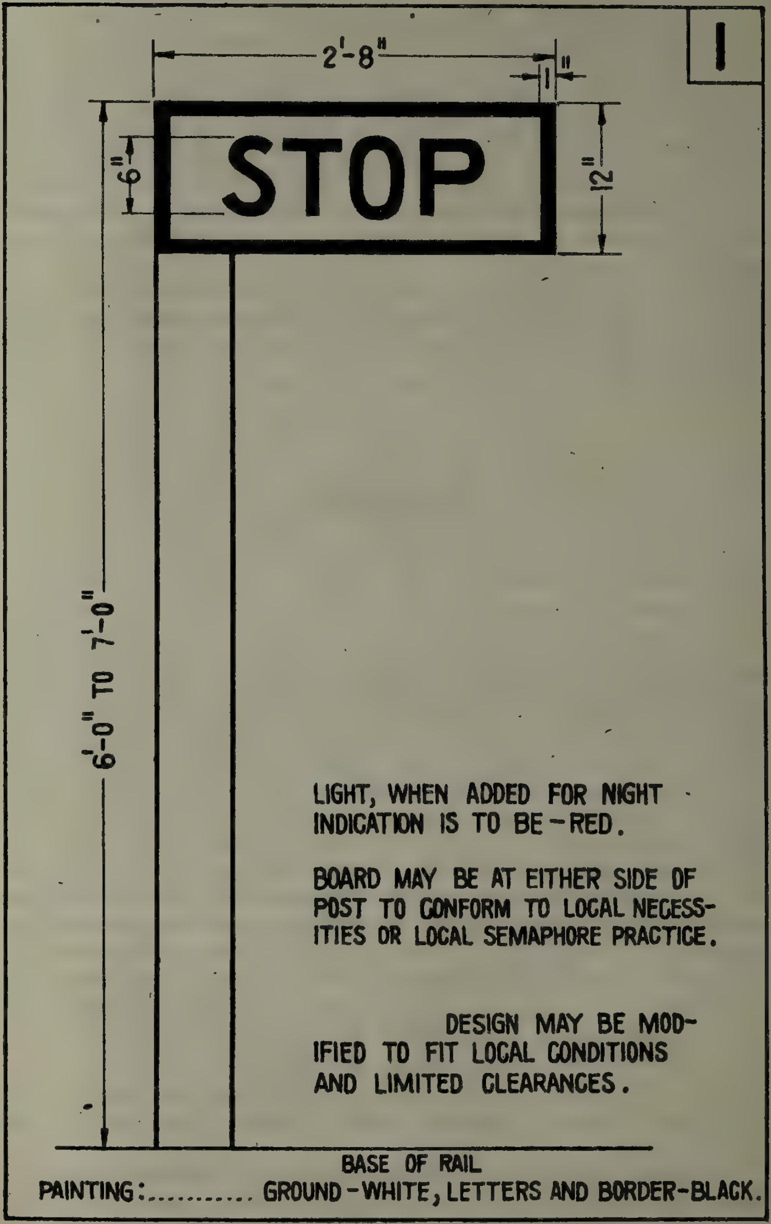


For the stop, speed-limit, and resume-speed signs (which affect all trains) we have followed the semaphore type and generally accepted aspects. For signs 4 to 9 inclusive, it was not practicable to follow the semaphore type, and we have, in these cases, considered that the object to be accomplished was the greatest visibility and distinguishability as to form. For signs 10 and 11, the signs in present use vary widely, but the variations do not appear to be material. We have submitted designs conforming to signs that are in quite general use.

We think that the limitations of restricted clearances are so varied that it is hardly practicable to design a sign to meet all conditions, and therefore suggest that the designs submitted may be modified to meet the requirements of each case. We are, however, submitting sketches 1-A, 2-A, 3-A, 4-A, 5-A and 10-A to indicate how the designs submitted may be modified to fit track spacing of thirteen feet without encroaching on the clearance limits recommended by the American Railway Engineering Association (see Proceedings, Volume 18, page 1257).

In these designs we have confined ourselves to outlines and not undertaken to specify materials from which the signs may be constructed.

We have not made any recommendations as to standard location of these signs. This appears to be an important matter and one in which uniformity is essential. On this point we would ask for further instructions.

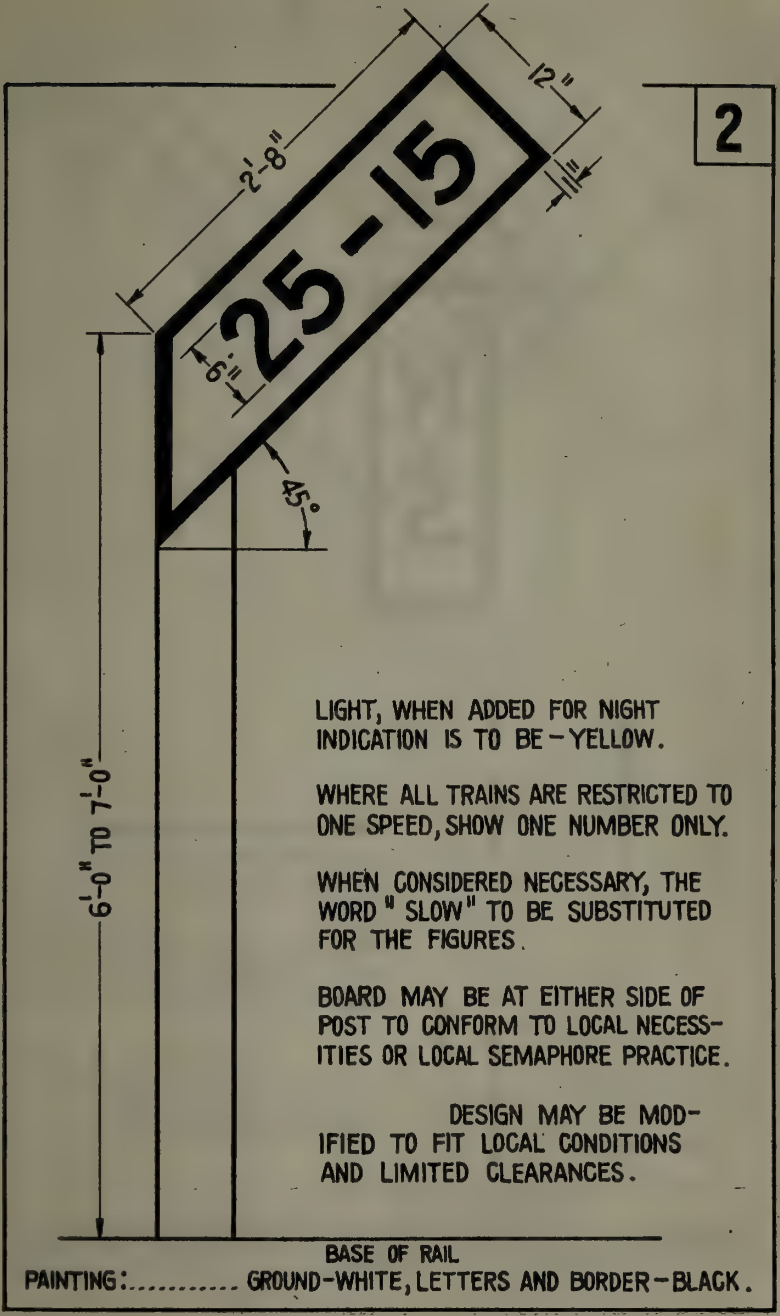


LIGHT, WHEN ADDED FOR NIGHT INDICATION IS TO BE—RED.

BOARD MAY BE AT EITHER SIDE OF POST TO CONFORM TO LOCAL NECESSITIES OR LOCAL SEMAPHORE PRACTICE.

DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCES.

PAINTING:.......... GROUND-WHITE, LETTERS AND BORDER-BLACK.



LIGHT, WHEN ADDED FOR NIGHT INDICATION IS TO BE–YELLOW.

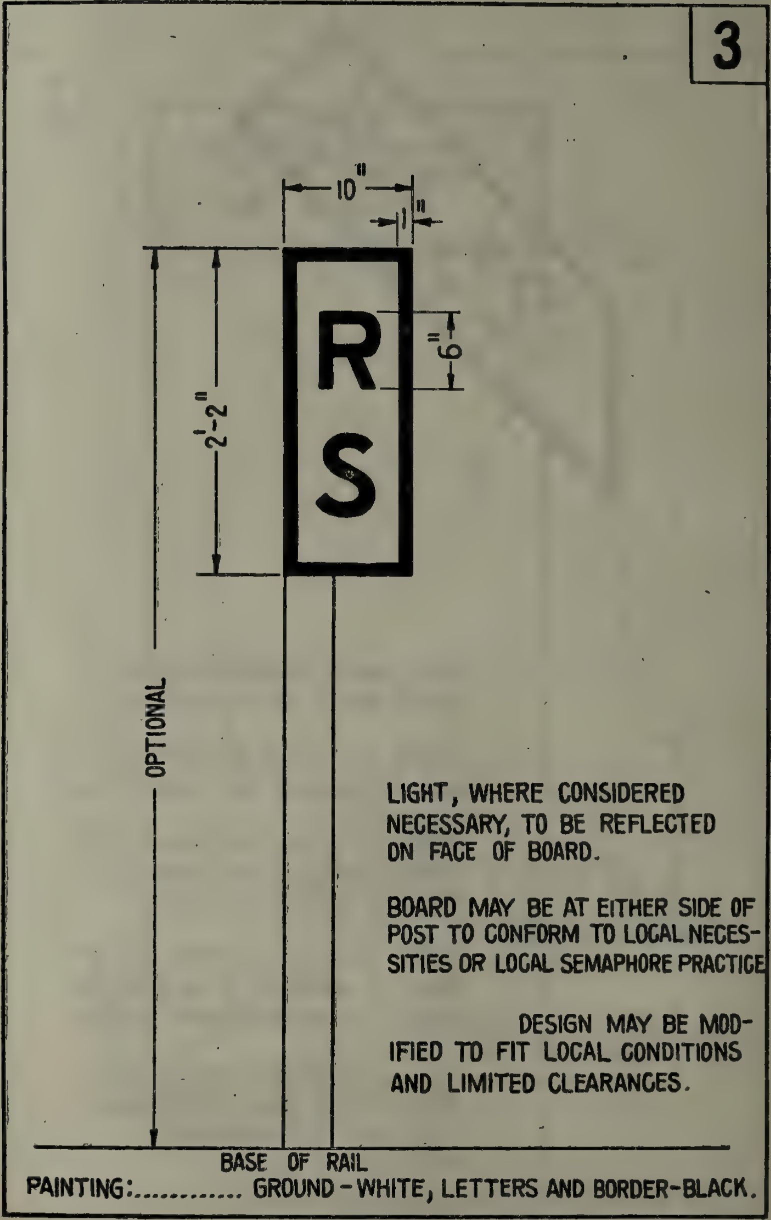
WHERE ALL TRAINS ARE RESTRICTED TO ONE SPEED, SHOW ONE NUMBER ONLY.

WHEN CONSIDERED NECESSARY, THE WORD " SLOW" TO BE SUBSTITUTED FOR THE FIGURES.

BOARD MAY BE AT EITHER SIDE OF POST TO CONFORM TO LOCAL NECESSITIES OR LOCAL SEMAPHORE PRACTICE.

DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCES.

PAINTING:............ GROUND-WHITE, LETTERS AND BORDER–BLACK.

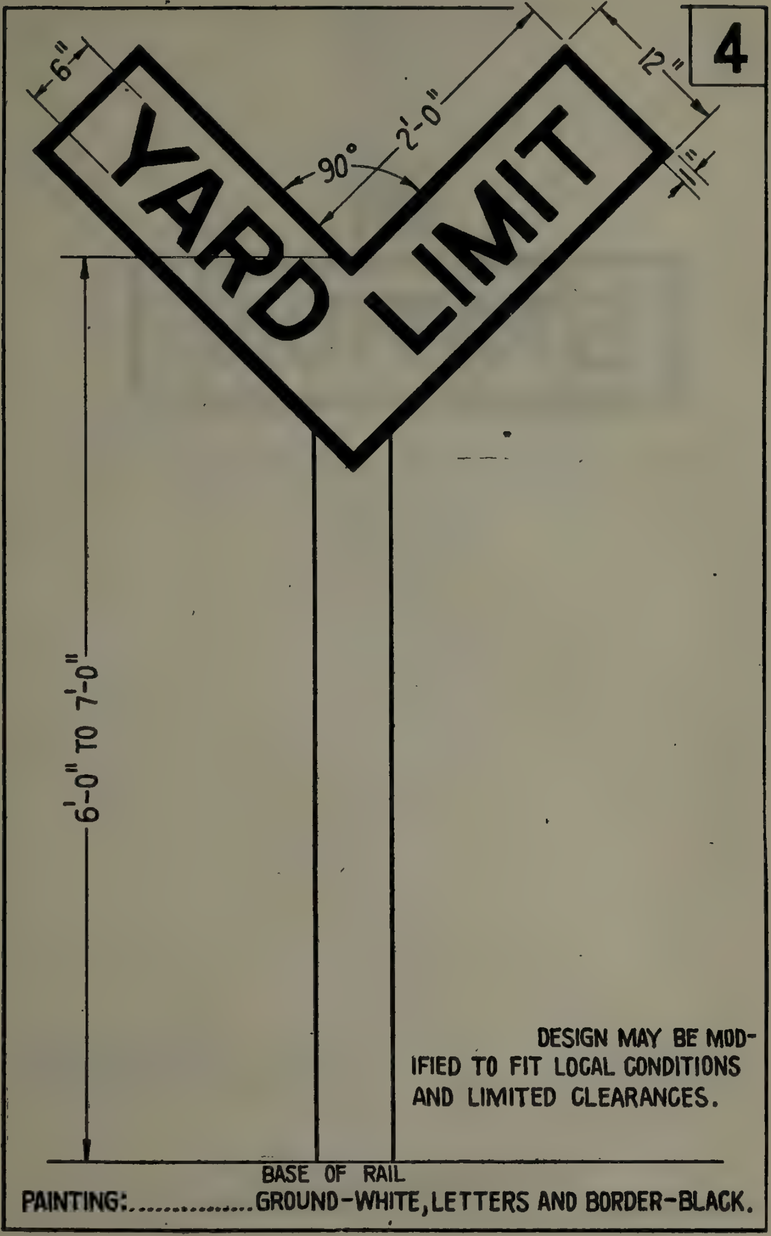


LIGHT, WHERE CONSIDERED NECESSARY, TO BE REFLECTED ON FACE OF BOARD.

BOARD MAY BE AT EITHER SIDE OF POST TO CONFORM TO LOCAL NECESSITIES OR LOCAL SEMAPHORE PRACTICE

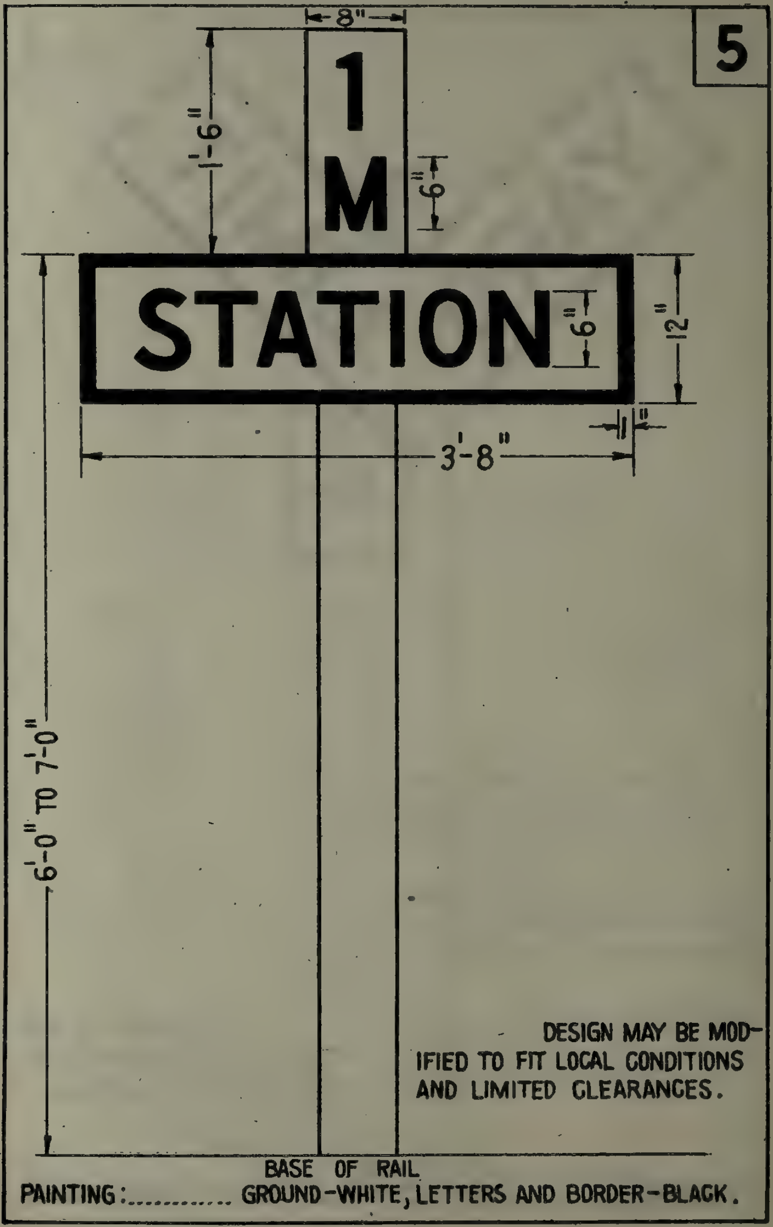
DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCES.

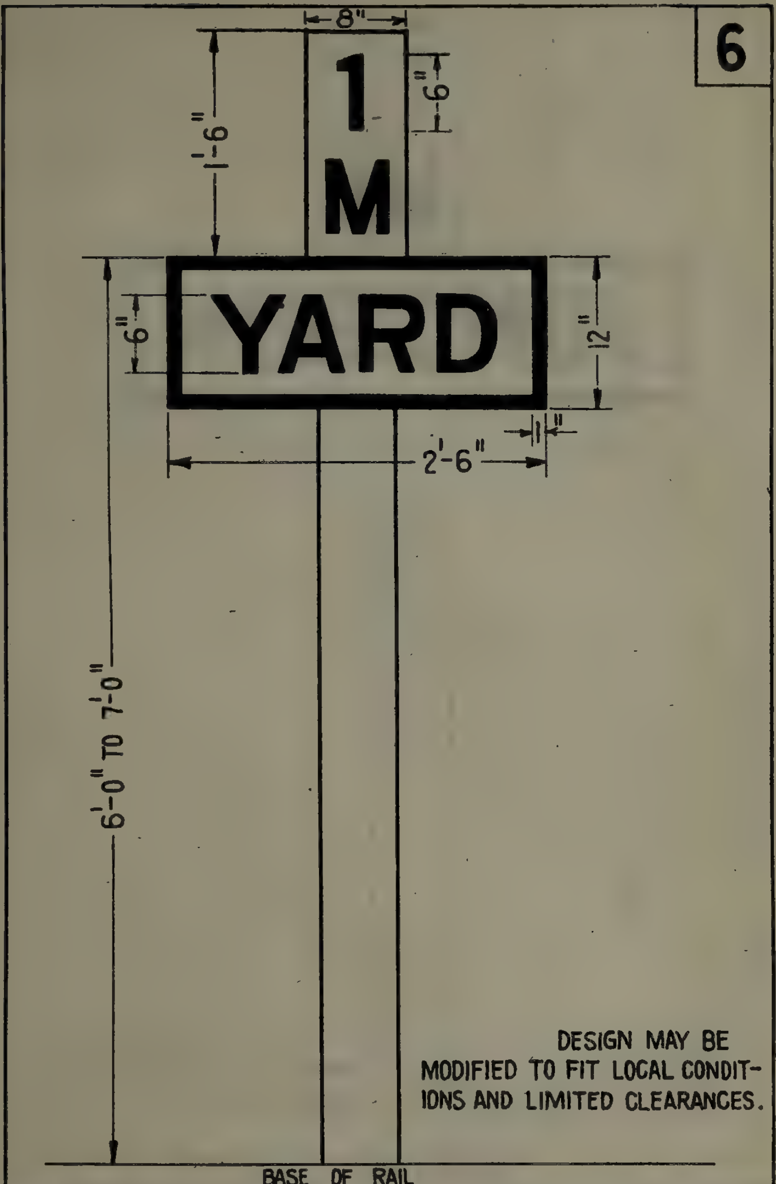
PAINTING:............ GROUND-WHITE, LETTERS AND BORDER-BLACK.



DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCES.

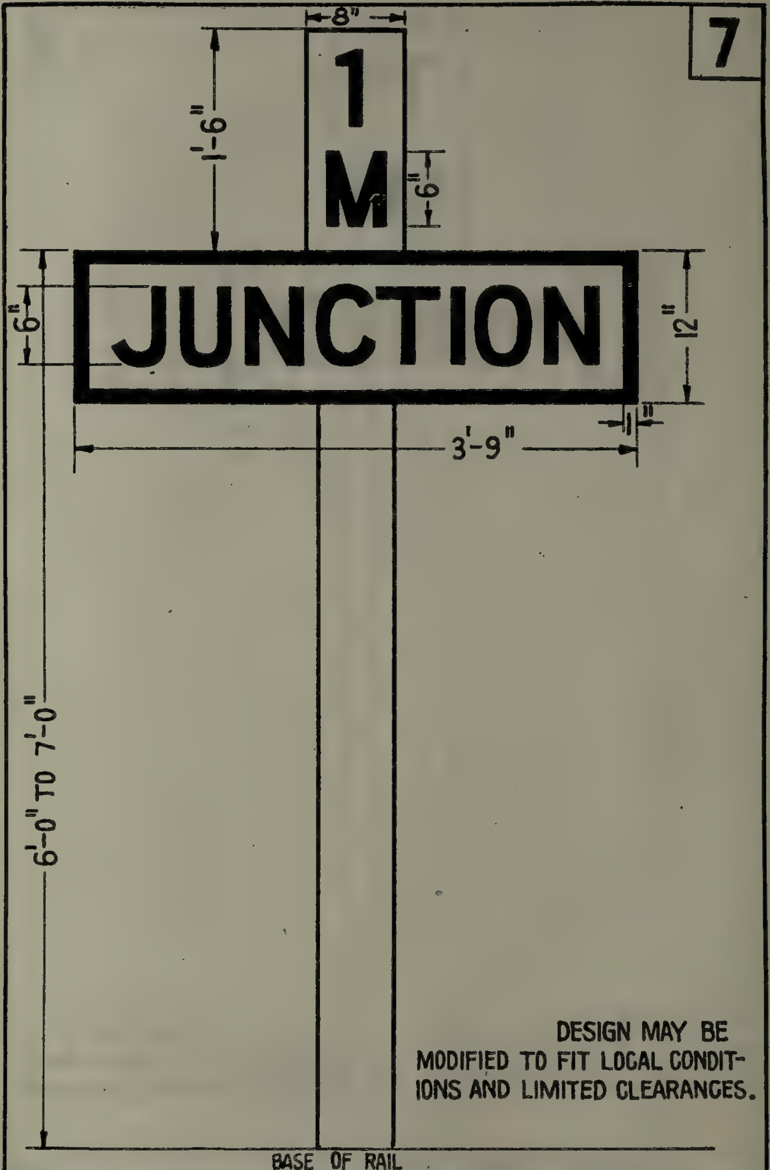
PAINTING:...............GROUND-WHITE, LETTERS AND BORDER-BLACK.


5
8"
1-6"
1
M
6"
STATION
6"
12"
1"
3'-8"
6'-0" TO 7'-0"
DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCES.
BASE OF RAIL
PAINTING:............ GROUND-WHITE, LETTERS AND BORDER-BLACK.



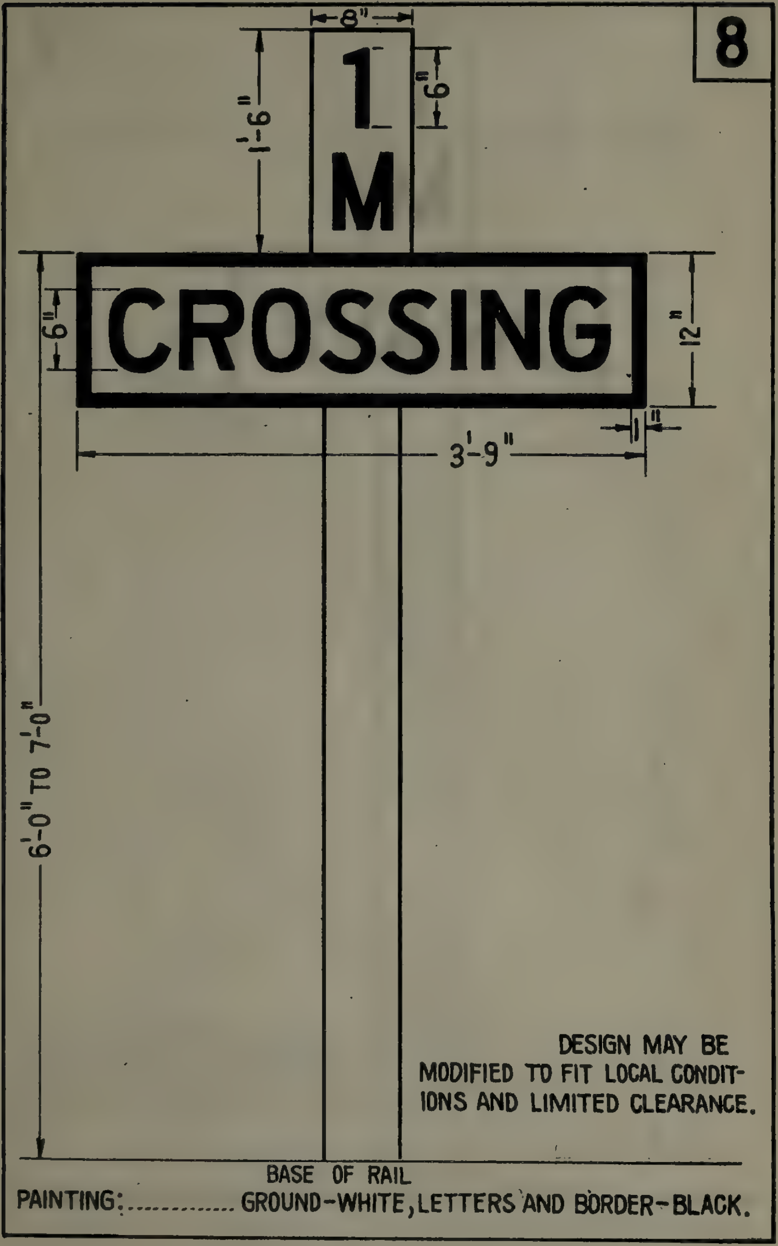
DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCES.

PAINTING:............. GROUND-WHITE, LETTERS AND BORDER-BLACK.



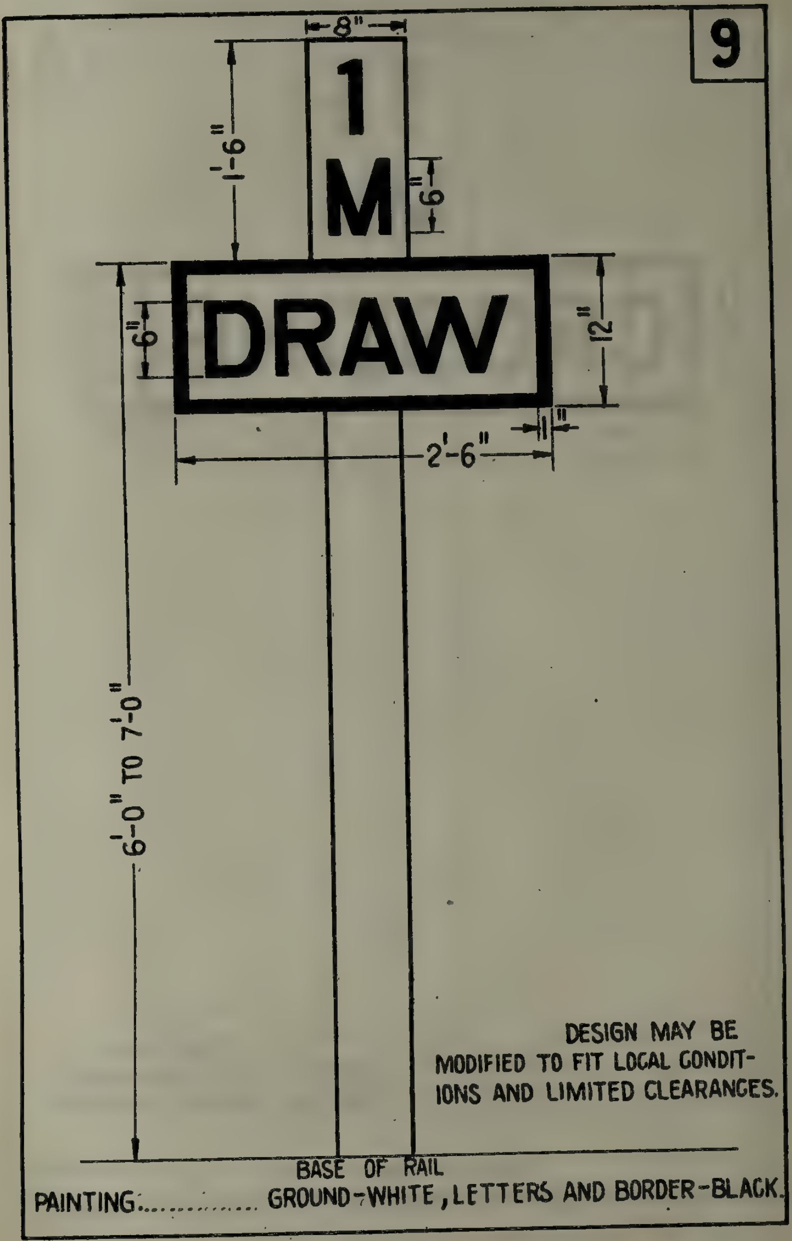
DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCES.

PAINTING:.............GROUND-WHITE, LETTERS AND BORDER-BLACK.



DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCE.

PAINTING:............. GROUND-WHITE, LETTERS AND BORDER-BLACK.

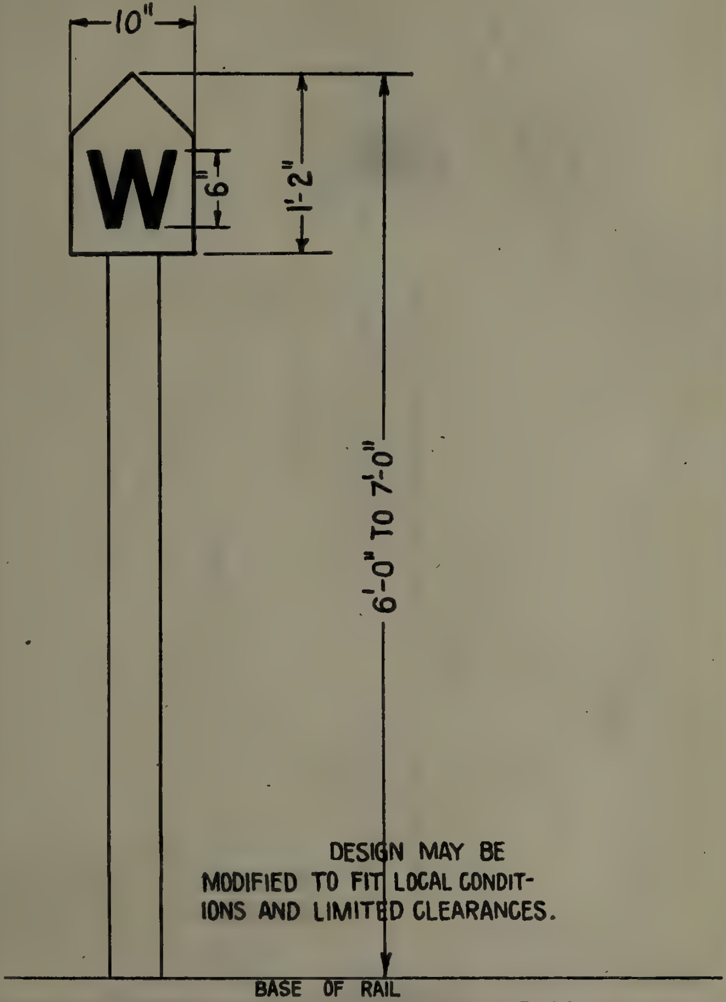


DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCES.

PAINTING:............ GROUND-WHITE, LETTERS AND BORDER-BLACK.

10

HIGHWAY CROSSING WHISTLE POST.



DESIGN MAY BE MODIFIED TO FIT LOCAL CONDITIONS AND LIMITED CLEARANCES.

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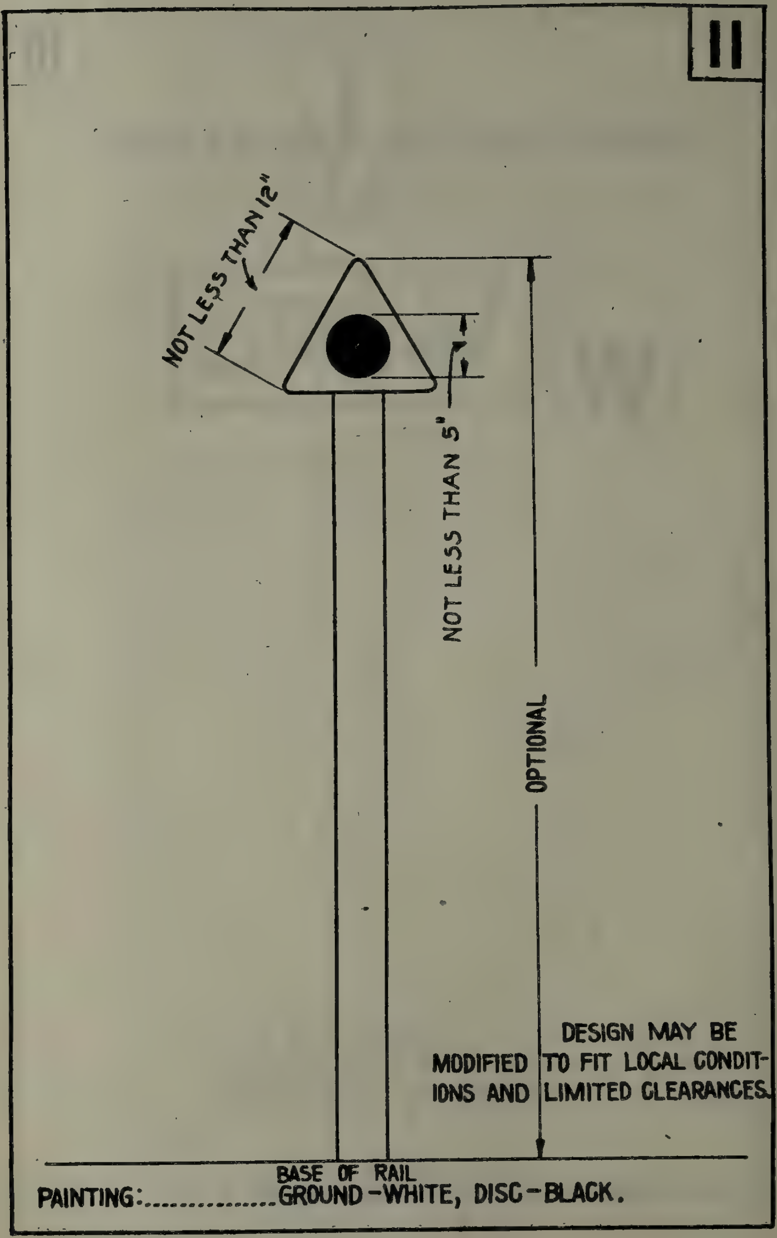
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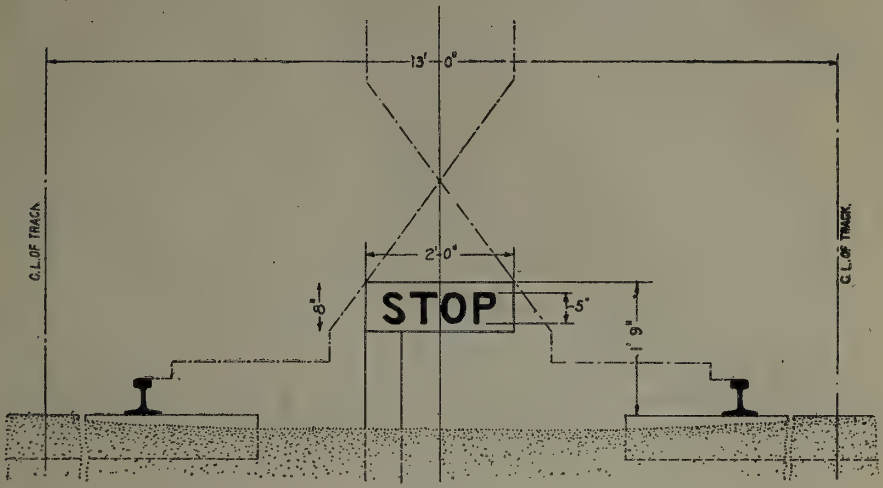

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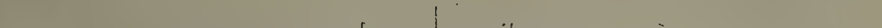

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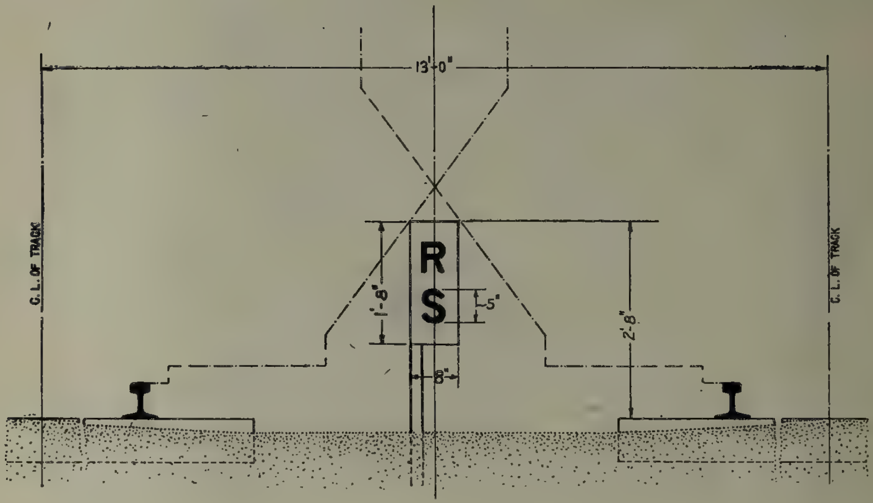

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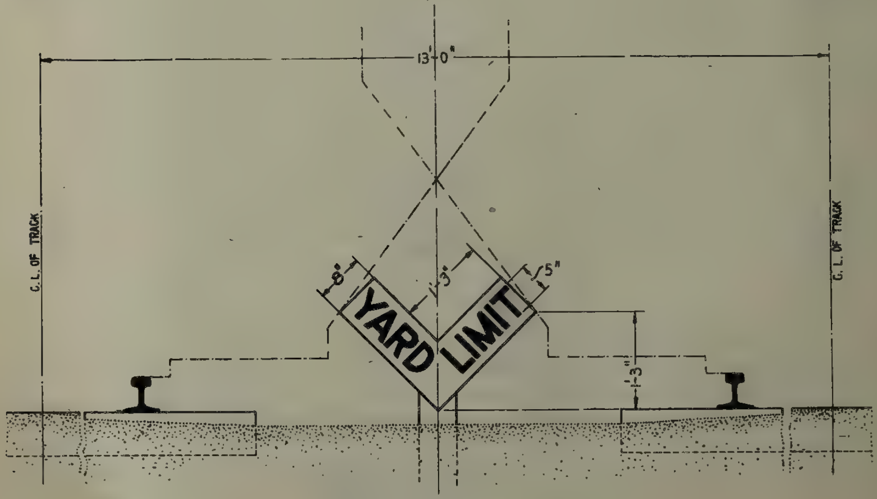

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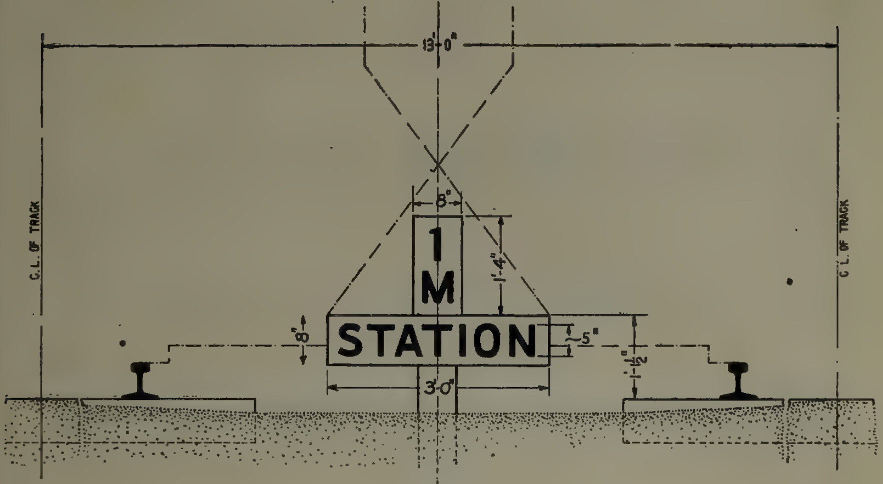

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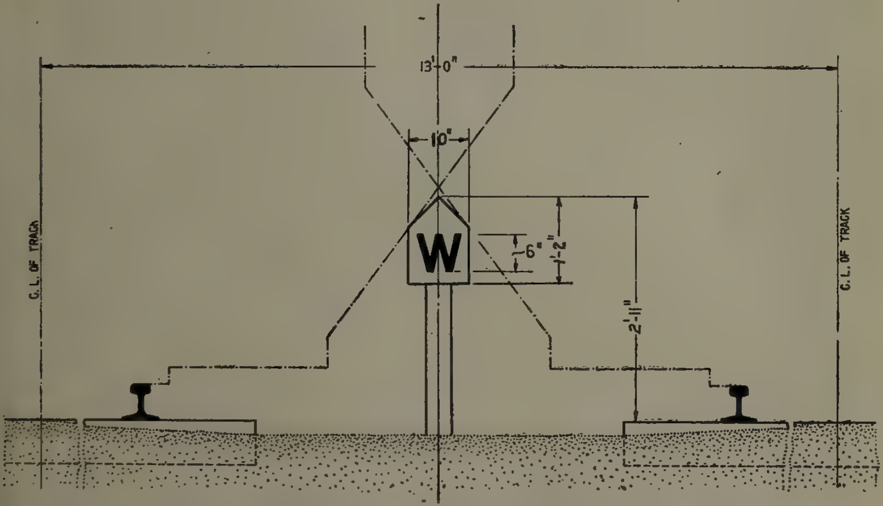

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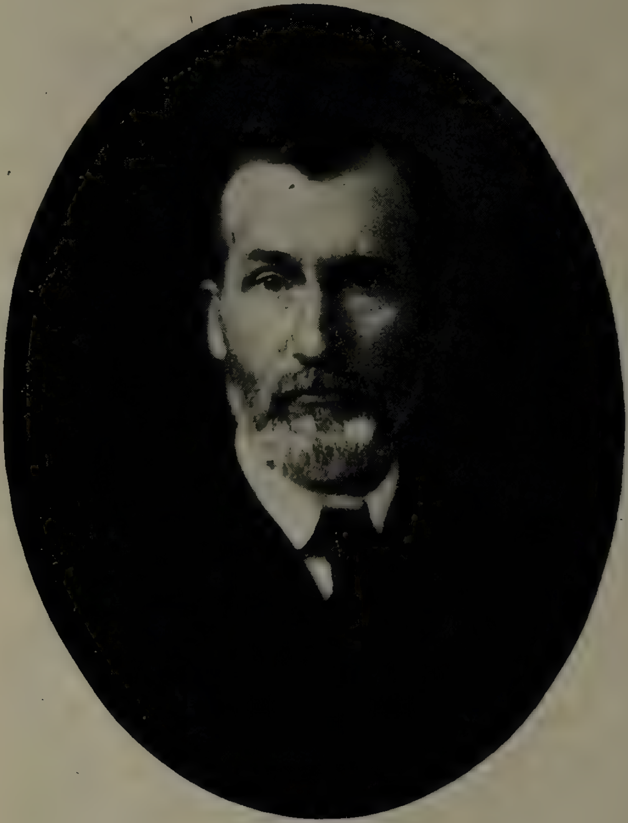
Charles Lee Crandall

A MEMOIR

American Railway Engineering Association
1917



C L Crandall

Charles Lee Crandall

A MEMOIR

Charles Lee Crandall was born at Bridgewater, N. Y., July 20, 1850, the second son of Peter B. and Eunice C. (Priest) Crandall. It was there and at the Whitestown Seminary, Whitestown, N. Y., that he obtained his early education and prepared for college.

At this time there is recalled a family tradition forecasting the character of his mature manhood. A boy of his own age brought a new sled to school. The older boys tormented him, took the sled away, and wrecked it badly. The boy, beginning to cry, was addressed thus by the future professor: "Don't cry, George. Bring your sled over to my house to-night and I will fix it for you." The sled was accordingly repaired and the incident proved a forward step in his development. He never could bear to see anyone unhappy and always wanted to help someone. Never a neighbor was ill or in financial straits but he was ready with time and purse to help him.

At the opening of Cornell University in 1868, Peter Crandall transferred his family to Ithaca that they might enjoy the educational advantages afforded by the new institution. He settled on a West Hill farm, Evergreen Terrace, overlooking the village of Ithaca and facing the new university on the heights beyond (East Hill), a most beautiful location and one well fitted for those who were to make it their home. On a summer evening, after a day of toil on "the hill," the throngs of students wending their way to the town below, the pealing of the chimes across the valley, and Cornell's beautiful campus illumined by the setting sun combine in a scene of rare enchantment, and one that is not forgotten by a visitor to the Crandall home.

Peter Crandall was a man of rugged character and strong convictions, one of the early New England type, and an ardent supporter of President Lincoln. Interested in all the better things of public life he became a member of Ithaca's first Board of Education and continued a prominent citizen for many years.

It was thus that the son, Charles, became a member of the first class at Cornell, and after completing the full four-year course received the degree of Bachelor of Civil Engineering in 1872. That his career as a student was marked by ability and honor was shown by the receipt of prizes in science and chemistry and the office of treasurer conferred by the members of his class. That office and the life secretaryship of his class were held by him at the time of his death.

In 1870, during his Junior year, he was honored by appointment as City Engineer of Ithaca, a position which he continued to hold for twenty years.

During the two years succeeding his graduation he was employed first by a local architect, and later as assistant engineer for the B. & M. Railroad. In April, 1874, he returned to enter upon his life-work as a teacher of Civil Engineering, and so became a member of that group of heroic men who bore the University's burdens in the time of its adversity, and who were rewarded in later life by seeing the institution for which they labored attain her present proud position in the world of education.

At first he taught a variety of subjects and continued his studies, earning for himself in 1876 the degree of Civil Engineer, which corresponds to the present degree of Master of Civil Engineering.

It was into the hands of this young man God placed the keeping of one of his most precious beings when, in 1878, he married Miss Myra G. Robbins of Bridgewater, N. Y. In her early womanhood Miss Robbins had suffered an illness which resulted in a total loss of sight. The affliction, although of a seriousness sufficient to break the spirit of almost anyone, was insufficient to overcome the courage of Miss Robbins or to close the eyes of our wise professor to her unusual worth and attractiveness. How well he was chosen for this sacred charge is shown by the words of a life-long friend who writes: "In the thirty-nine years Mrs. Crandall and he have lived together he has never mentioned her affliction, nor has he ever felt that it should change her life in any way."

To be eyes for his early companion was the lofty aim that sanctified his soul, and throughout the long years of their married life his loving faithfulness was evidenced by her interesting accounts of their journeys, the things "we saw," the people "we met," given with such accuracy and enthusiasm that the affliction was lost in the charm of her conversation. The visit of the American Society of Civil Engineers to London in 1889, and again to the World's Fair in San Francisco in 1915, gave her especial pleasure, and she returned from both with most vivid recollections of the many interesting scenes and events of those tours.

In the home circle matters of current interest and of importance to the family were discussed freely in order that all members might be fully informed and give free expression to their views and preferences. In this manner there developed a mutual interest and interdependence which carried them pleasantly through a lifetime of unusual activity and care.

That Professor Crandall's reputation for fair-dealing with his students was well developed at this early date is shown by the following incident related by one of the best-known graduates. Two students whose exuberance of life could not be extinguished by geodesy and least squares, were engaged in a controversy regarding the possibilities of ponying on examinations conducted by various professors. In the course of the controversy some bets were made and a sturdy Irishman of unusual character was challenged to pony under Professor Crandall, when he quickly replied, "What, Crandall? No. I'll not pony under Professor Crandall. He's fair."

For many years he directed the practice surveys of the students in geodesy and railroad engineering, continuing the latter until his retirement in 1915. The geodetic surveys comprised a triangulation of many of the lakes of central New York together with soundings and topographical surveys of the surrounding country. The high character of this work, although performed by students, permitted its incorporation in the maps of the United States

Geological Survey and of the United States Lake Survey.

The railroad work consisted of running trial lines in and about Ithaca, the problems including the elimination of the present switchback on the D. L. & W. Railroad at Ithaca, a trial line to Elmira across Enfield Gorge, and the relocation of the Lehigh Valley Railroad near East Ithaca.

It was in this practical outdoor work that he came in closest contact with the students and won their respect and admiration by his systematic ways and the skill and thoroughness of his instruction. This respect and admiration were quickly supplemented by a strong affection among all those students who because of some unusual need received his direct personal attention and assistance, and these feelings of respect, admiration, and affection grew continuously in after life as the graduates learned from day to day and year to year that their progress in the profession was greatly enhanced by the painstaking and thorough instruction secured in his classes. That accuracy of detail which is the leading characteristic and pride of the profession was his especial forte, and to find an error in the work of the professor was one of the rarest events of a student's life.

Many of the principles which he sought to impress upon the minds of the students have not been reported in modern works of engineering. One of these was stated by a '92 man as follows: "I recall once he said to me, when about to start upon Saturday railroad work and it was raining slightly and we were debating whether to go or not to go, 'If you have planned to do something out-of-doors and it rains, go ahead. Nine times out of ten you will win. The other time you get drenched.'" He frequently remarked that he had never known a good man to be spoiled by the lack of money, but possessed abundantly it often did great harm.

Students were always required to work out their field notes in the evening after a day of arduous work. Though trying at times, especially to young men of no previous discipline, its wisdom is known to field engineers, and indeed the habit became so fixed in the life of the professor that it continued to the end of his life. It was a theme for volumes for the training of engineers to see him steal away after a day of close application to all the details of the sessions of the American Railway Engineering Association in its Annual Convention to review carefully the day's events and fix correctly in his mind their important features. At these Conventions, so freely attended by engineers from all over the continent, the temptation is strong to enjoy the pleasures of social intercourse, making use of the rare opportunity to meet friends and co-workers from distant points, such a meeting being frequently an event to be remembered for many years.

But the social part of his life was not neglected. In his journeys about the country, it was always a pleasure to his former students to entertain and be entertained in turn by him, and these visits became a regular part of his life.

With the growth of the University, the increased size of the classes, and the consequent enlargement of the teaching staff, there came opportunities for selection in the subjects to be taught. Geodesy, Bridge and Railroad Engineering had claimed his chief attention, but with increasing demands upon his time, bridges and geodesy were assigned to other departments. A full professorship was attained in 1895 with the title of Professor of Railway Engineering and Geodesy. From 1908 to 1915 he was Professor of Railroad Engineering.

While attending to the duties of teaching he contributed freely to the literature of engineering. Besides notes and papers for professional societies and technical journals, he published from time to time "Tables for Computation of Railway and Other Earthwork," "Notes on Descriptive Geometry," "Notes on Shades, Shadows, and Perspective," "The Transition Curve," "Geodesy and Least Squares," "A Field Book for Railroad Surveyors," and jointly with Professor Barnes a valuable book called "Railroad Construction." Of these books it may be said that they were not easy reading for the careless student, but for accuracy and practical usefulness they have great merit.

Among men of learning his intellectual attainments were appropriately recognized by membership in the honorary scientific societies, Tau Beta Pi and Sigma Xi, and by his choice for the presidency of the Society for the Promotion of Engineering Education in 1905-1906.

Professor Crandall always kept in touch with his graduates through the medium of a student association of engineers of which he was Corresponding Secretary. In this way he obtained a continuous record of the addresses and business connection of all his graduates, seeking to build up the College through the maintenance of their interest and assistance and at the same time to further the aims of the graduates by keeping them informed in matters of business interest, assisting them in changes of location and employment.

In 1892 the Association undertook the publication of an engineering journal, now called the Cornell Civil Engineer. To this he gave his most indefatigable attention, and with the aid of students and alumni succeeded in bringing it to the present standard of permanence and excellence.

This linking together of the interests of the college and its graduates has brought about the well-known camaraderie of the alumni which finds its highest expression in the non-professional organization known as the Cornell Society of Civil Engineers.

Professor Crandall was Acting Director of the College of Civil Engineering in 1892-1893 during the absence of Professor Fuertes, and again from the death of the latter in January, 1903, until the appointment of Professor Haskell, the present Dean, in 1906. In these two critical periods he administered the affairs of the College with great diligence and carried the work of his professorship as well.

Professor Crandall was not unmindful of the important relations of the University and the student body to the profession at large, and early identified himself with leading professional societies. In 1876 he joined the American Society of Civil Engineers and acquired full membership in that body in 1892. In 1901 he became a member and active worker in the American Railway Engineering Association, serving on the Committee on Iron and Steel Structures from its formation in 1902 until his death. The work of this Committee has been of such unusual interest and importance as to bring to the Association distinction and honor in no small degree. And to Professor Crandall is due full share of the credit for its achievements. His services were of particular value in the investigation of impact on railway bridges, a technical and scientific study of high order and one that will remain a permanent contribution to bridge engineering. His paper, entitled "A Review of the Development of Metal Bridges," appearing in Volume XI, Part 1, of the Proceedings (1910), was a valuable contribution to the literature of the Association.

In appreciation of his services on the Committee and of the high regard in which he was held by its members, the following resolution was adopted at its October meeting:

"Whereas, on August 25, 1917, Professor C. L. Crandall was called away by death:

Be it resolved by the members of the Committee on Iron and Steel Structures of the American Railway Engineering Association, in session at Chicago, October 18, 1917, that in the death of Professor Crandall the Association has lost one of its most valued members. Especially do the members of the Committee mourn the loss of a most faithful and devoted worker and friend. Always, during his many years' membership on this Committee, ready to respond to any assignment of task, safe and sound in judgment, helpful and considerate in criticism, he was a man whose example was an inspiration to his fellow-workers.

"Resolved that an engrossed copy of these resolutions be conveyed to his bereaved widow, to whom the Committee extends its sincere sympathy."

In 1917 he became a member of the Committee on Economics of Railway Location.

Professor Crandall's connection with the Association was marked by constant faithfulness and his co-workers could not fail to observe his unusual interest. A well-known member with whom he had been closely associated writes that the Professor looked upon his work with the Association as a duty which he owed to his College, believing it to be a matter of prime importance that his institution should co-operate freely and enjoy the advantages of close relationship to the Association.

It was not easy for the chance acquaintance to properly estimate his worth because of the extreme modesty which prevailed in all of his more formal relations. It is, therefore, of unusual interest to read a communication from an intimate associate that a certain prominent member of the Association has frequently expressed his great delight in becoming acquainted with Professor Crandall during the impact measurements on his road. He had never known the Professor very well and had supposed him to be rather taciturn, and was both delighted and surprised to discover his generous fund of quiet humor and love for a joke regardless of where it might hit.

Our fellow-member, Sylvester N. Williams, Professor-Emeritus of Civil Engineering of Cornell College, Mt. Vernon, Iowa, was a college classmate of Professor Crandall, and their interchange of compliments at the Conventions were filled with interest for their chance companions.

Although a man of unusual industry and faithfulness to the duties of his occupation, he found time to take an active interest in the public affairs of the municipality in which he lived. In addition to his long service as City Engineer, he assisted in framing the charter under which Ithaca became a city, and was a member of the Board of Public Works at the time of his death.

Professor Crandall was a lifelong friend and supporter of the Unitarian Church, and had been for many years a member of its Board of Trustees.

His retirement from active duty in accordance with the University age limit took place July 20, 1915, when he was elected Professor-Emeritus by the Board of Trustees. This action caused slight relaxation from his wonted industry. His active outdoor life and careful living had prolonged both mental and bodily powers beyond the usual age, and at the time he was giving his last instruction in field surveying, there were many younger men who would have been unable to follow him throughout the day.

The close of his teaching career brought to him a shower of honors from every quarter. Resolutions of appreciation and good-will were passed by Trustees and Faculties and other interested bodies. But the most impressive demonstration of regard took place in New York at the Annual Dinner of the Cornell Society of Civil Engineers. This event was arranged especially to do him honor, and a much less modest man could only have been highly gratified by the enthusiastic and affectionate ovation.

At this dinner announcement was made of a fund subscribed in small amounts by the alumni for the establishment of the Charles Lee Crandall prize and the gift to the College of a full-sized oil portrait of the Professor. The prize was to consist of the sums of $100 and $50 to be awarded annually for the most noteworthy papers presented by undergraduates of the College, on some one of a group of special subjects selected, each year, to encourage original research and stimulate intelligent interest in those engineering problems which most directly concern the public welfare; both the selection of these special subjects and the conditions governing the award of the prize to be prescribed in detail by Professor Crandall himself.

The succeeding two years brought little in the way of rest. There was much unfinished business laid aside for a rainy day, and many former clients were eager to secure his services. Having always been closely identified with New York Surveys it is not surprising that we read in a dispute concerning property lines, the statement of a contestant, "If you can get Professor Crandall to come out here and survey that line and say where it should go, we will accept his word that it should go there." And again with respect to a wider practice, "None but his family will miss him more than our lawyers who accepted his services as unerring."

His office in Lincoln Hall was retained to the end, and the affairs of the College received much attention. He was never busier than at the time of his death, and it seemed to his friends that he had twice the amount of work ahead that an ordinary man could still perform. It is of especial interest to know that only a short time before his death he had again revised and corrected the complete list of graduates of the College, and when clearing up his desk it was found that everything was prepared to continue his work on the following day.

The final parting from his life of active labor, from his persistent endeavor and final triumph, and from the beloved members of his family, took place on August 25, 1917, at the end of a brief illness. In company with Mrs. Crandall, he had been enjoying a respite from his labors in Bridgewater, at the home of Mrs. Scott, a sister of Mrs. Crandall. Returning to Ithaca, he resumed his practice and spent all of Monday, the 13th, in the open on Cornell Heights. At night he became feverish and soon developed a severe attack of pneumonia. Complications arose in the digestive organs, and were followed quickly by his demise.

The announcement of his sudden death brought to the University, the community in which he lived, and to his friends in distant cities, the most profound sorrow, and was followed by many testimonials of affection and respect. The following from an editorial in the Ithaca News was written by a man who felt keenly the loss of a friend of thirty years:

"Professor Crandall's home has for many years been one of the most charming places in Ithaca. Married to a wife of unusual social and intellectual attainments, there have been few places in the city where university students and teachers, as well as townspeople, have found more helpful and inspiring intercourse. Both Professor Crandall and his wife have kept up correspondence with many former students, in all parts of the United States, rejoicing in their successes, and helping them in times of adversity. The loving devotion of Professor Crandall and his wife to each other was most touching, and hundreds of loving friends have hearts full of sympathy for the sorrowing wife and daughter who have been so suddenly bereaved."

The Engineering News-Record gave an account of his life and made editorial mention of the event, including therein the following paragraph:

"Success of the more material sort came to Professor Crandall of Cornell University, whose death was noted in last week's issue, but the crowning professional success, the affectionate regard of forty engineering classes, was his in exceptional measure. Kindliness and sympathy were the lodestones by which he attracted the young men, and forever kept them as friends; but to these traits he added a sureness of technical knowledge that made him in after years a professional mentor as well. His work and the place he holds in the memory of his boys should be an inspiration to every teacher. He showed how great a success can be made in the teaching profession."

The press report of the burial services conducted by the Rev. H. A. Pease, in the Unitarian Church, includes the following:

"He was generous to those who needed him and an inspiration to the young men of our city and university and a loss indescribable to his loved ones and to thousands of Cornellians and to thousands of our own residents. Professor Crandall's eulogy is in every heart, and although he needs none, we feel it and pronounce it as a tribute of duty to such a lofty and beautiful and blessed soul, a soul that has bequeathed to us his mortality and the memory of his glorious day in our midst."

Besides the representatives of the Church, the University, and the City, there were in attendance at the funeral many former students and friends from out of town who had learned of his death in time to be present at this final event of his career. Among these visitors was a delegation from the Cornell Society of Civil Engineers.

Many friends who lived too far or who were advised too late to attend the funeral have exhibited the keenest sense of their loss in letters filled with tenderness and sorrow. Of these the following expresses the prevailing thought:

"Professor Crandall was a ***man.*** As Professor of Engineering he has left with me most pleasant memories of my life at Cornell. His fatherly ways rather than harsh tones and commands probably influenced more the life of young men under him than any of us really appreciate. He was instructor, confessor, and father all in one. His passing away has left with me a sore which will take long to heal."

Another tribute of great feeling and sincerity has risen to the superlative in the following lines:

"Very soon after arriving in Ithaca, I realized what an unusual personality Professor Crandall was and how deeply he was loved and respected by all. I had always had my ideal of service to my students, but it had never been my good fortune to be intimately associated with a man who embodied it. He seems to have attained the ideal of Christ in his sympathy, love and help. I hope I may in my imperfect way do for this University a work which will be better for having known and come under the influence of Professor Crandall. Largely because of him those years at Cornell were the richest of my life, and it is my wish that the blessing be shed on others besides myself."

Professor Crandall is survived by his widow, Myra R. Crandall, a younger brother, Clayton Crandall, who is a former councilman of the city of Ithaca, a sister, Mrs. Ella O. de Mello, of Santos, Brazil, and an adopted daughter, Miss Emma Bowers. An older brother, Kirk P. Crandall, now deceased, was for many years City Engineer of Ithaca.

While attending to the many affairs of his busy life, Professor Crandall did not fail to provide for the material welfare of his loved ones, and their many friends will rejoice to know that the bereaved family will continue to reside at Evergreen Terrace, surrounded by the comforts and attractions of former years.

To the reader it will now be clear that Professor Crandall was a man of very unusual character, but this record falls far short of a full portrayal of the man and the qualities through which his personality has been stamped indelibly upon Cornell and the profession of engineering. The well-rounded development, great breadth of view, his simple charity, and perennial kindliness have all been shown, but for the countless acts of his daily life through which the summit was finally attained there is no space.

In the family he was the rock to which all members turned instinctively from harm. For students he had an abounding faith that repeated failures could not shatter. Neighbors looked to him as one omniscient, and would call for aid in trivial matters with childlike faith in his ability and willingness to furnish the desired relief. To them it was not unfitting that the writing of a textbook on geodesy should be laid aside to repair a leaky pipe and that an overworked professor should be their banker without gain. The serious acceptance of these neighborly duties contrasted strongly with the greed sometimes displayed in business life, but there was still material prosperity in a modest way and no fear that Providence could be unkind.

Nor does the record show the familiar figure journeying back and forth across the town to his daily work for nearly fifty years. On foot, with carriage, bicycle, street car, and automobile, each in turn, he made the three-mile journey for "an eight o'clock" on "the hill," returning again to the home at night. Small wonder that the people knew Professor Crandall. He was a part of Ithaca itself, a trusted landmark of the town.

In some vague way the belief was held that buttoned beneath his calm exterior, hidden from the gaze of man, there was a diamond clear and sparkling, something holy, a source of power. We did not know, we could not, all the virtues of his life. We did not know his faults were virtues. Only God and his dear wife could see with clearness all his acts and know the people's visions were just plain, hard facts. We laid him gently on the hillside looking o'er the lovely plain, there to rest in peace and quiet, ne'er to see his face again. And with slow and heavy footsteps as we journeyed down the hill, there were angels all around us, calling softly, Peace, be still.

Prepared by A. J. Himes, Willard Beahan, H. S. Jacoby, F. E. Turneaure, John G. Sullivan, former students of Professor Crandall, with the exception of Professor Jacoby, and he was a colleague in the Cornell Faculty.

American Railway Engineering Association

VOL. 19, No. 20. . . . . NOVEMBER, 1917.

MEMBERS OF THE AMERICAN RAILWAY ENGINEERING ASSOCIATION IN THE MILITARY OR NAVAL SERVICE OF THE UNITED STATES, AND ITS ALLIES.

The following is a list of members of the American Railway Engineering Association in the military or naval service of the United States, the Canadian Expeditionary Forces, or the British Army. Military titles have been omitted; these will be given in a future Bulletin.

W. K. Adams, Quartermaster's Office, Fort Sam Houston, Texas.

Azel Ames, Consulting Signal Engineer, New York City.

W. G. Arn, Assistant Engineer Maintenance of Way, Illinois Central Railroad, Chicago.

W. G. Atwood, Assistant District Engineer, Interstate Commerce Commission, Chattanooga, Tenn.

H. Austill, Bridge Engineer, Mobile & Ohio Railroad, Mobile, Ala.

J. S. Bassett, Assistant Engineer, Missouri Pacific Railroad, Monroe, La.

R. P. Black, University Engineer, University of the South, Sewanee, Tenn.

F. C. L. Bond, Division Engineer, Grand Trunk Railway, Montreal, Canada.

H. C. Booz, Assistant Chief Engineer, Pennsylvania Railroad, Philadelphia, Pa.

V. T. Boughton, Resident Engineer, Canadian Pacific Railway, Sudbury, Canada.

Richard Brooke, Assistant Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

C. E. Carson, Superintendent, Fort Dodge, Des Moines & Southern Railway, Boone, Iowa.

W. A. Cattell, Consulting Engineer, San Francisco, Cal.

W. B. Causey, Vice-President, Norwood-White Coal Company, Des Moines, Iowa.

C. W. Cochran, Engineer Maintenance of Way, Cleveland, Cincinnati, Chicago & St. Louis Railway, Galion, Ohio.

C. S. Coe, Engineer Maintenance of Way, Florida East Coast Railway, St. Augustine, Fla.

W. C. Coles, Pilot Engineer, Baltimore & Ohio Railroad, Wheeling, W. Va.

C. K. Conard, Chief Engineer, Davison Sulphur & Phosphate Company, Cienfuegos, Cuba.

R. A. Cook, Valuation Engineer, Chicago & Alton Railroad, Chicago.

E. B. Cushing, Assistant General Manager, Southern Pacific Lines in Texas and Louisiana, Houston, Texas.

A. M. Davidson, Assistant Engineer, Baltimore & Ohio Southwestern Railroad, Cincinnati, Ohio.

J. W. Dawson, Engineer Maintenance of Way, Missouri, Oklahoma & Gulf Railway, Muskogee, Okla.

G. P. DeWolf, Assistant Superintendent, International & Great Northern Railroad, San Antonio, Texas.

J. V. Dillabough, Office Engineer, Hudson Bay Railway, The Pas, Canada.

H. T. Douglas, Jr., Chief Engineer, Chicago & Alton Railroad, Chicago.

W. J. Eck, Signal and Electrical Engineer, Southern Railway, Washington, D. C.

Raffe Emerson, Consulting Engineer, New York City.

G. B. Farlow, Assistant Engineer, Baltimore & Ohio Railroad, Cincinnati, Ohio.

T. W. Fatherson, Engineer Maintenance of Way, Chicago Great Western Railroad, Des Moines, Iowa.

S. M. Felton, President, Chicago Great Western Railroad, Chicago.

J. R. Fordyce, Consulting Engineer, Little Rock, Ark.

C. M. Goodrich, Designing Engineer, Canadian Bridge Company, Walkerville, Canada.

F. W. Green, Assistant to Vice-President, St. Louis Southwestern Railway, St. Louis, Mo.

F. H. Gross, Instrumentman, Interstate Commerce Commission, Chicago.

B. W. Guppy, Engineer of Structures, Boston & Maine Railroad, Boston, Mass.

R. F. Hamilton, Boise, Idaho.

C. L. Hervey, Consulting and Contracting Engineer, Montreal, Canada.

F. G. Hoskins, Superintendent, Baltimore & Ohio Railroad, Wheeling, W. Va.

H. W. Hudson, Engineer of Foundations and Masonry, New York Connecting Railway, New York City.

L. J. F. Hughes, Division Engineer, Chicago, Rock Island & Pacific Railway, Herington, Kansas.

V. R. Irvine, Cost Engineer Valuation, Texas & Pacific Railway, Dallas, Texas.

J. B. Jenkins, Valuation Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

F. G. Jonah, Chief Engineer, St. Louis-San Francisco Railroad, St. Louis, Mo.

S. C. Jump, Assistant Engineer, Illinois Central Railroad, Chicago.

E. B. Katte, Chief Engineer Electric Traction, New York Central Railroad, New York City.

G. A. Kenrick, Assistant Engineer, Northern Pacific Railway, Spokane, Wash.

Paul M. LaBach, Assistant Engineer, Rock Island Lines, Chicago.

F. E. Lamphere, Assistant Engineer, Baltimore & Ohio Chicago Terminal, Chicago.

F. Lavis, American International Corporation, New York City.

P. S. Lewis, Passenger Trainmaster, Philadelphia & Reading Railway, Reading, Pa.

R. J. Lockwood, Vice-President and General Manager, Appalachicola Northern Railway, Port St. Joe, Fla.

J. deN. Macomb, Jr., Office Engineer, Atchison, Topeka & Santa Fe Railway, Chicago.

John Maher, Assistant Engineer, Cincinnati, Hamilton & Dayton Railroad, Cincinnati, Ohio.

L. V. Manspeaker, Assistant Engineer, Chicago & Alton Railroad, Springfield, Ill.

G. L. Mattice, Ross Rifle Factory, Quebec, Canada.

A. A. McCree, Vancouver, Wash.

C. H. Miller, President, Miller Engineering Co., Little Rock, Ark.

R. M. Miller, Assistant Engineer, Virginian Railway, Norfolk, Va.

F. A. Molitor, Consulting Engineer, New York City.

C. N. Monsarrat, Chairman and Chief Engineer, Quebec Bridge, Montreal, Canada.

C. W. P. Ramsey, Engineer of Construction, Canadian Pacific Railway, Montreal, Canada.

G. W. Rathjens, Vice-President, Twin City Brick Company, St. Paul, Minn.

J. G. Reid, Assistant Engineer, Canadian Pacific Railway, Estevan, Canada.

J. W. Reid, Bridge Engineer, Chicago & Alton Railroad, Chicago.

J. H. Richardson, Bridge Designer, Lehigh Valley Railroad, South Bethlehem, Pa.

E. M. Rosher, Glenside, Surrey, England.

T. E. Rust, Chief Engineer, Waterloo, Cedar Falls & Northern Railway, Waterloo, Iowa.

E. C. Schmidt, Professor of Railway Engineering, University of Illinois, Urbana, Ill.

A. G. Shaver, Consulting Electrical and Signal Engineer, Chicago.

L. E. Silcox, Division Engineer, Hudson Bay Company, The Pas, Canada.

P. T. Simons, Washington, D. C.

H. J. Slifer, Consulting Engineer, Chicago.

H. J. Smith, Civil Engineer, Interstate Commerce Commission, Washington, D. C.

W. W. Smith, Assistant Engineer, Grand Trunk Railway, Montreal, Canada.

Geo. D. Snyder, Deputy Chief Engineer, Hudson & Manhattan Railroad, New York City.

J. L. Taylor, Jr., Assistant Engineer, Pennsylvania Lines West, Pittsburgh, Pa.

J. E. Teal, Assistant Engineer, Baltimore & Ohio Railroad, Baltimore, Md.

A. T. Tomlinson, Inspector Small Arms, Lindsay Arsenal, Canada.

T. G. Townsend, Timber Treating Inspector, Southern Railway, Washington, D. C.

W. M. Vandersluis, Signal Engineer, Illinois Central Railroad, Chicago.

W. K. Walker, Engineer Maintenance of Way, Wabash Railway, St. Louis, Mo.

D. A. Wallace, Ottawa, Canada.

J. H. Wasson, Recorder, Division of Valuation, Interstate Commerce Commission, Chicago.

P. J. Watson, Jr., Assistant Engineer, Chicago & Alton Railroad, Chicago.

G. H. Webb, Chief Engineer, Michigan Central Railroad, Detroit, Mich.

W. L. Webb, Public Utility Engineer, Philadelphia, Pa.

R. C. White, Superintendent, Missouri Pacific Railroad, Wynne, Ark.

C. L. Whiting, Supt., Chicago, Milwaukee & St. Paul Ry., Lewiston, Mont.

W. J. Wilgus, Consulting Engineer, New York, N. Y.

H. P. Wilson, Assistant Valuation Engineer, Texas & Pacific Railway, Dallas, Texas.

ADDITIONS TO MEMBERSHIP.

1992. Jukichi Fuzine,
Chief Engineer, Sze-cheng Railway, Ssupinkai, Manchuria, China.

2004. R. L. Alexander,
Assistant Engineer, Chicago, Milwaukee & St. Paul Railway, Minneapolis, Minn.

2005. D. L. Woodruff,
Supervisor Bridges and Buildings, Texas & Pacific Railway, Marshall, Texas.

2006. F. S. Wheeler,
Division Engineer, Erie Railroad, Buffalo, N. Y.

2007. J. M. Fair,
Supervisor, Pennsylvania Railroad, Philadelphia, Pa.

2008. A. W. Neel,
Assistant Engineer, Presidents' Conference Committee, New York, N. Y.

ENGINEERING SOCIETIES CLUB OF HAWAII.

An "Engineering Societies Club" has been established in Honolulu, Hawaii, the main purpose of the Club being for the entertainment of visitors from the various national engineering organizations while in Honolulu or the Hawaiian Islands.

A member of any of the following engineering associations is eligible for membership of this Club: American Railway Engineering Association; American Society of Civil Engineers; American Society of Mechanical Engineers; American Institute of Mining Engineers; American Institute of Electrical Engineers; American Society of Naval Engineers; American Society for Testing Materials.

Request has been made that publicity be given to the formation of this Club and to the fact that the privileges of the Club are extended to members of the various technical organizations while visiting Honolulu.

Any member of the American Railway Engineering Association proposing to visit Honolulu or the Hawaiian Islands should make it a point to announce himself to the Secretary of the Engineering Societies Club of Hawaii, Mr. E. F. Cykler, so that such member may be properly taken care of.

CHANGES OF TITLE AND ADDRESS.

Mr. John C. Sesser has been promoted to Assistant General Superintendent, Great Northern Railway, with headquarters at Great Falls, Mont.

Mr. Carl Bucholz, heretofore Assistant Superintendent, has been promoted to the office of Superintendent, Erie Railroad, with headquarters at Youngstown, Ohio.

Mr. W. E. Burkhalter has been appointed Division Engineer of the Mobile & Ohio Railroad at Murphysboro, Ill.

Mr. C. H. Ewing, heretofore General Manager of the Philadelphia & Reading Railway, has been promoted to Vice-President of the same company.

Mr. Harold Knight has been made Superintendent of Maintenance of Way of the Erie Railroad, with office at New York City.

Mr. Frank Lee has been transferred from Winnipeg, Canada, to Montreal, as Engineer Maintenance of Way of the Eastern Lines of the Canadian Pacific Railway.

Mr. A. C. Mackenzie has been transferred to Winnipeg, Canada, from Montreal, as Engineer Maintenance of Way of the Western Lines of the Canadian Pacific Railway.

Mr. J. R. Savagae, heretofore Chief Engineer, has been appointed General Manager of the Long Island Railroad, with office at Jamaica, N. Y.

Mr. R. E. Woodruff, heretofore Superintendent of the Mahoning Division of the Erie Railroad, at Youngstown, Ohio, has been promoted to Superintendent of Transportation of the same company.

RESEARCH FELLOWSHIPS IN THE ENGINEERING EXPERIMENT STATION, UNIVERSITY OF ILLINOIS.

To extend and strengthen the field of its graduate work in engineering, the University of Illinois maintains fourteen Engineering Experiment Station Research Fellowships. One other such fellowship has been established under the patronage of the Illinois Gas Association. These fellowships, for each of which there is an annual stipend of $500.00, are open to graduates of approved American and foreign universities and technical schools. Appointments to these fellowships are made and must be accepted for two consecutive collegiate years, at the expiration of which period, if all requirements have been met, the degree of Master of Science will be conferred. Not more than half of the time of the Research Fellows is required in connection with the work of the department to which they are assigned, the remainder being available for graduate study.

Nominations to these fellowships, accompanied by assignments to special departments of the Engineering Experiment Station, are made from applications received by the Director of the Station each year not later than the first day of February. The nominations are made by the Station Staff subject to the approval of the Executive Faculty of the Graduate School and the President of the University. Nominations are based upon the character, scholastic attainments, and promise of success in the principal line of study or research to which the candidate proposes to devote himself. Preference is given those applicants who have had some practical engineering experience following their undergraduate work. Appointments are made in the spring and they take effect the first day of the following September. Vacancies may be filled by similar nominations and appointment at other times.

The Engineering Experiment Station, an organization within the College of Engineering, was established in 1903 for the purpose of carrying on investigations in the various branches of engineering, and for the study of problems of importance to engineers and to the manufacturing and industrial interests of the State. Research work may be undertaken in architecture, architectural engineering, ceramic engineering, chemistry, civil engineering, electrical engineering, mechanical engineering, mining engineering, municipal and sanitary engineering, physics, railway engineering, and in theoretical and applied mechanics.

The work of the Station is closely related to that of the College of Engineering, and the Heads of Departments in the College constitute the administrative Station Staff. Investigations are carried on by members of the Station Staff and other members of the instructional staff of the College of Engineering, by special investigators employed by the Station, and by the Research Fellows.

Additional information may be obtained by addressing

The Director,
Engineering Experiment Station,
University of Illinois,
Urbana, Illinois.

BULLETIN

OF THE

American Railway Engineering Association

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W. D. PENCE, *Editor*,
Chicago, Ill.

E. H. FRITCH, *Secretary*,
910 Michigan Avenue,
Chicago, Ill.

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V. K. Hendricks, Assistant Chief Engineer, St. Louis-San Francisco Railroad, St. Louis, Mo.

S. T. Wagner, Chief Engineer, Philadelphia & Reading Railway, Philadelphia, Pa.

American Railway Engineering Association

VOL. 19, No. 202 . . . . DECEMBER, 1917

FOREWORD.

Beginning with the November number, the Bulletins to be issued prior to the ensuing convention will contain Committee reports to be acted on at the annual convention in March next.

In order to make the meetings of the annual convention interesting and profitable, it is essential to have full and free discussion of the Committee reports on the floor, which will bring about corrections and improvements, if required, and at the same time furnish additional information from the experiences of the speaker or writer.

That the discussions may be such as to accomplish the above result, it is advisable that each member study the reports carefully as soon as issued in the Bulletin, and prepare in advance the data and information which he desires to give to the Association while taking part in the debate.

Members who may be unable for special reasons to attend the annual convention are requested to send to the Secretary written discussions of such reports in which they are particularly interested.

Members are requested to bring their Bulletins containing committee reports to the convention, as the supply of extra copies is limited. Additional copies will be furnished to members during the convention at cost.

JOHN G. SULLIVAN,
President.

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REPORT OF COMMITTEE V—ON TRACK.

G. J. Ray, *Chairman;*	J. R. Leighty, *Vice-Chairman;*
M. C. Blanchard,	H. A. Lloyd,
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T. H. Hickey,	Thomas Quigley,
T. T. Irving,	J. B. Strong,
J. B. Jenkins,	W. P. Wiltsee,

Committee.

To the American Railway Engineering Association:

Your Committee on Track respectfully submits its report to the Nineteenth Annual Convention.

The following subjects were assigned your Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.
2. Report on typical plans of turnouts, crossovers, slipswitches and double crossovers, and prepare detail plans for such work, including such incidentals as tie-plates, rail braces, riser plates, etc., conferring with Committee on Signals and Interlocking.
3. Report on reduction of taper of tread of wheel to 1 in 38 and on canting the rail inward.
4. Report on test of tie-plates subject to brine drippings.
5. Report on specifications for relayer rail for various uses.
6. Consider the advisability of reducing allowable flat spots on freight car wheels, collecting data as to damage done by flat spots.
7. Consider design of cut track spikes.
8. Report upon the effect of fast trains upon the cost of maintenance of way and equipment.
9. Report on whether widening of the flange of the wheels would not be detrimental to the present standard of track construction.
10. Report on guard rails and flangeways and effect of increase of ⅛-inch thickness of wheel flanges.

COMMITTEE MEETINGS.

Meetings of the whole Committee were held in Chicago on May 31 and October 15, in addition to the meetings held by the various Sub-Committees.

(1) REVISION OF MANUAL.

In Appendix A proposed changes in the Manual are given.

(2) TYPICAL PLANS OF TURNOUTS, CROSSOVERS, SLIP-SWITCHES AND DOUBLE CROSSOVERS AND DETAIL PLANS FOR SUCH WORK.

In Appendix B the Committee submits detail plans as per instructions.

(3) REDUCTION OF TAPER OF TREAD OF WHEEL TO 1 IN 38 AND ON CANTING THE RAIL INWARD.

The Committee reports on this subject in Appendix C and submits the matter as information.

(5) SPECIFICATIONS FOR RELAYER RAIL FOR VARIOUS USES.

In Appendix D the Committee reports on specifications for relayer rail for various uses and recommends their adoption under the heading of Conclusions.

(7) DESIGN OF CUT TRACK SPIKES.

In Appendix E the Committee resubmits the design of cut track spike presented to the convention in 1917 and recommends its adoption under the head of Conclusions.

(8) THE EFFECT OF FAST TRAINS UPON THE COST OF MAINTENANCE OF WAY AND EQUIPMENT.

In Appendix F the Committee submits as information a discussion of the effect of fast trains upon the cost of maintenance of way and equipment.

(9) WIDENING OF FLANGER OF THE WHEELS.

In Appendix G the Committee reports on the subject of "Whether widening of the flanger of the wheels would not be detrimental to the present standard of track construction," assigned to this Association by the American Railway Association.

PROGRESS REPORT.

The Committee reports progress on subjects (4) Test of tie-plates subject to brine drippings; (6) Consider the advisability of reducing allowable flat spots on freight car wheels, collecting data as to damage done by flat spots.

CONCLUSIONS.

Your Committee makes the following definite recommendations to the Association:

Receive as Progress Report:

(To be considered further at the next convention.)

Subject (2) Plans submitted for:

Typical plan of No. 10 turnout and typical layout of No. 10 crossover.
16 ft. 6 in. split switch, style "A."
16 ft. 6 in. split switch, style "A" details.
16 ft. 6 in. split switch, style "B."
16 ft. 6 in. split switch, style "B" details.
No. 8 rigid frog, style "A" and style "B."
No. 10 rigid frog, style "A" and style "B."
No. 6 rigid frog, style "A" and style "B."
Sections and details for rigid frogs.

For Adoption and Publication in the Manual:

Subject (1) Proposed revisions to be made in the Manual.

Subject (5) Proposed specifications for relayer rails for various uses.

Subject (7) Proposed design of cut track spike.

Accept as Information:

Subject (3) Report on reduction of taper of tread of wheel to 1 in 38, and on canting the rail inward.

Subject (8) Report upon the effect of fast trains upon the cost of maintenance of way and equipment.

Subject (9) Report on whether widening of the flange of the wheels would not be detrimental to the present standard of track construction.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends for next year's work: Continuation of Subjects (1), (2), (3), (4), (6), (8) and (9).

Respectfully submitted,

THE COMMITTEE ON TRACK.

Appendix A.

(1) REVISION OF MANUAL.

Your Committee recommends that the seventh line from the bottom of page 119 of the Manual, under Specifications for Steel Tie-Plates, viz., "Plates must be both properly and thoroughly annealed," be eliminated, and substituted after line seven from the top of page 121, under Specifications for Wrought Iron Tie-Plates.

On typical plan of No. 8 turnout, the following changes should be made:

(a) Short curved lead rail in turnout is shown 16 ft. 7⅞ in. and should read 16 ft. 7¼ in.

(b) Offset (Y-2) shown on plan as 2 ft. 10⅞ in. and should read 2 ft. 9¾ in. In the table on page 185 of the Manual 2.91 ft. is shown and should be changed to 2.81 ft.

Plan of 16 ft. 6 in. switch shows center to center of heel ties 21 in., and should be made to read 10½ in. from center of first heel tie to joint, as is shown on turnout plan.

Plan of 22 ft. switch shows center to center of heel ties 21 in., and should be made to read 10½ in. from center of first heel tie to joint, as is shown on turnout plan.

Plan of 33 ft. switch shows 17 spaces at 19 in. and then 20 in. spacing, the No. 16 turnout shows 18 spaces at 19 in. and then 20 in. spacing. The turnout spacing agrees with the entire lead length and should be used.

All switch plans should be changed to show 10½ in. from center of tie joint. Omit the tie spacing at joint and use turnout plans for tie spacing beyond switch heel.

For the present, your Committee does not believe it necessary to further change the tie-plate specifications, but recommends that this subject be given careful consideration by the next Committee.

Appendix B.

(2) TYPICAL PLANS OF TURNOUTS, CROSSOVERS, SLIP-SWITCHES AND DOUBLE CROSSOVERS, AND DETAIL PLANS FOR SUCH WORK, INCLUDING SUCH INCIDENTALS AS TIE-PLATES, RAIL BRACES, RISER PLATES, ETC.

Your Committee submits herewith the following detail plans:

- Typical plan of No. 10 turnout and typical layout of No. 10 crossover.
- 16 ft. 6 in. split switch, style "A."
- 16 ft. 6 in. split switch, style "A" details.
- 16 ft. 6 in. split switch, style "B."
- 16 ft. 6 in. split switch, style "B" details.
- No. 8 rigid frog, style "A" and style "B."
- No. 10 rigid frog, style "A" and style "B."
- No. 6 rigid frog, style "A" and style "B."
- Sections and details for rigid frogs.

No. 10 Turnout and Crossover:

Drawings are herewith submitted showing typical plan of No. 10 turnout and typical layout of No. 10 crossover to conform with those now in the Manual for No. 8 turnout and crossover.

16 Ft. 6 In. Split Switch (Style "A"):

The 16 ft. 6 in., style "A," switch submitted is a development of 16 ft. 6 in. switch shown on page 176 of the 1915 Manual, with changes that were thought advisable.

The throw has been recommended as 4½ in. at center line of switch-head rod, which brings the throw at the end of the point 4$\frac{13}{16}$ in. The throw is specified at end of point to be not less than 4 in. or greater than 5 in. On page 178 in the 1915 Manual the throw is specified 5 in. center of No. 1 rod, which would make the throw 5$\frac{5}{16}$ in. at the point. Your Committee considers this excessive.

The risers for style "A" switch is specified $\frac{5}{16}$-in., which affords a better shoulder for holding the stock rail in position, especially for heavy flange rails, than the ¼-in. specified on pages 178 and 179 of the 1915 Manual.

The angle of planing chamfer cut has been specified as 78 deg., as the 70-deg. angle specified on page 179 in the 1915 Manual is generally considered too abrupt and is not in common use.

The switch point planing has been specified in much fuller detail and conforms to planing extensively used.

The detail of slide plates has been specified to admit the use of a rectangular plate or of special rolled plates having risers narrower than the width of the plate, sufficient detail being given so that the plates and braces will be interchangeable.

The heel plates have been specified to provide a shoulder, both for the lead rails and the stock rails, and the tie spacing given so that the same detail of plates will apply for turnouts Nos. 7 to 10, inclusive.

The bars are specified 1 in. by 2½ in., instead of ¾-in. by 2½ in., as specified on page 180 of the 1915 Manual, and other details to conform to heavier materials now being largely used.

16 Ft. 6 In. Split Switch (Style "B"):

Style "B" switch has been developed for use where materials for style "A" switch has been considered heavier than warranted on Class B or Class C railways, and also for emergency requirements.

On style "B" switch the plates have been detailed 6 in. wide and a lesser quantity than specified for style "A" switch.

The tie bars are ¾-in. by 2½ in., reinforcing on one side only. Planing, spacing of tie bars, spread, throw and essential details are the same as specified for style "A" switch.

Style "B" switch is especially intended where style "A" switch is considered too expensive, and where the track is not tie-plated throughout.

No. 8 Rigid Frog:

No. 8 frog has been detailed 13 ft. 0 in. long, instead of 13 ft. 6 in. long, as specified on page 184 in the 1915 Manual, the 6 in. difference in length being made on the heel end of the frog. This change will not interfere with theoretical alinement data heretofore published. The reason for the change is so that a No. 8 frog will cut out of a 33 ft. 0 in. rail without waste in cutting. This is an important item of economy. If the 13 ft. 6 in. length is maintained the frog would not cut economically out of a 33 ft. 0 in. rail, unless the wing rails are made too short for a first-class frog.

No. 10 Rigid Frog:

No. 10 frog has been detailed 16 ft. 6 in. long, conforming to previous established length, and will cut out of a 33 ft. 0 in. rail with comparatively little waste.

No. 6 Rigid Frog:

No. 6 frog has been detailed 10 ft. 0 in. long as this length provides ample room for splice bars. A longer frog has been considered objectionable in a sharp turnout.

Plans have been detailed for style "A" and style "B" frog in each case. Style "A" frog, with cast filling, is similar to what is being used on many of the large eastern railroads, while style "B" frog, with rolled filling, is similar to what is being used on many of the western railroads.

Both styles of frogs are widely used and are proposed for standard without recommendations as to which is the best. The cost will be practically the same, and there are arguments in favor of each style.

General Notes.

An effort has been made to make the plans complete, embodying all the notes necessary, without separate specifications. It is intended that, if the plans submitted meet general approval, the Committee will prepare plans for other angle frogs, and switch lengths for turnouts, crossovers and slip switches for presentation at the next convention.

Therefore it would seem advisable not to make any changes in the Manual until after the detail plans herewith submitted have been fully considered and discussed by the Association. If the plans are later approved, the Manual can then be revised and the one set of plans will be complete.

On account of the importance of the subject, your Committee solicits full discussion of the plans not only on the floor of the convention, but by correspondence with the Committee during the coming season. Such changes as may seem desirable will be made, and the Association will be asked to approve the plans at the 1919 convention

Appendix C.

(3) REPORT ON REDUCTION OF TAPER OF TREAD OF WHEEL TO 1 IN 38 AND ON CANTING THE RAIL INWARD.

Wheel Taper:

At an early period in the history of car building, it was found that a certain amount of cone in the tread of a new wheel was advantageous from many viewpoints. The amount of coning varied until 1878 the ratio of 1 in 38 was adopted by the M.C.B Association. This remained the standard until 1907, when the association revised the taper, making it 1 in 20, the present standard. 1 in 20 coning is very generally used and might be said to be the world's standard. It is generally used in Canada, England, France, Germany, Russia, China, Japan and other countries, where the practice is about equally divided between uniform taper and slight double taper.

The loss of metal from the flange and tread of the wheel and from the rail is due to rubbing or slipping friction rather than to rolling friction. For economical wearing value the surfaces in contact must roll on each other with a minimum of rubbing and sliding. True rolling motion results when the wheel is traveling parallel to the rail without slipping. The tread of the wheel and surface of the rail must have proper contact to result in the least sliding friction.

When a wheel rests on the rail, the location of the point of contact depends upon the taper of the wheel and the radius of the top of the rail. The normal position of the rails in track is with the vertical axes parallel and at right angles to the plane of the track. In this normal position the point of contact of wheels having a coning of 1 in 20 and rail of A.R.A. section with 14-in. top radius of head is slightly less than ¾-in. inside of the center of the rail toward the gage side. For wheels having a coning of 1 in 38 the point of contact is slightly less than ⅜-in. inside of the center of rail toward the gage side.

This eccentric loading appears to be a condition that should be corrected. It has been the practice of section foremen to incline, or cant, the rail slightly to distribute wear over the top of the head or, as he calls it, "covering" the rail. The result obtained is to bring the point of contact over the center of the rail. This is the trackmen's position for economic wear and service of rail.

The heavier taper is carried on an inclined surface and produces stresses on the outside of flange of rail 40 per cent. to 50 per cent. greater than stress on inside flange due to outward thrust, as has been shown by the results obtained by the Committee on "Stresses in Track."

It has been suggested that heavier coning with the resultant eccentric load on rail accounts for the location of transverse fissures on the gage side of the rail. While they are most common on the gage side, their appearance at the center and outside of the head would seem to indicate that they are developed in the line of contact or application of load.

With the heavier coning the surface of the rail gradually wears to an inclined surface similar to the cone of the wheel. In this condition the abrasion of metal and slippage resistance is considerably increased.

Car wheel manufacturers have claimed that heavy taper supplies the condition favorable to true rolling motion and reduces to a minimum sliding of surfaces in contact. The following test has been quoted to verify their claims: Test made on Atchison, Topeka & Santa Fe Railway covered the complete service record of 4,272 chilled iron wheels placed under 534 new gondola cars of 100,000 lbs. capacity, placed in service June, 1907.

> "These wheels were made with 1 in 15 tread taper. A complete check was made monthly of all wheels removed, and, after four years' service, but two had been removed for wearing hollow and eight for sharp flange. Three of these, however, were ground to proper contour and again placed in service. After a period of six years 80 per cent. of the wheels were still in service."

It has been contended that flat taper tends to wheel oscillation, thereby increasing flange wear. On a dynagraph car equipped with cylindrical wheels of 1 in 38 taper, which has made about 300,000 miles, wearing out several sets of cast iron wheels, it was observed in the riding of this car that there was a noticeable freedom from oscillation. Also, these cylindrical treads have never developed a sharp flange and the smooth riding of car has been frequently commented upon.

In one instance, with coning of 1 in 20 on the cast iron wheels with only a width of tread of 1⅞ in. before the 5/16-in. chamfer occurs; it is claimed that the deformation of rails on the gage side has become so great that the contact between the wheel tread and rail head is now reduced in many places to ¼-in. to ⅝-in. in width. This concentrates entirely too much pressure upon the head of rail in small limits for good wear and service.

Excessive wear on frogs is an objection to heavier coning. A wheel with a heavy cone trailing through a frog has its load carried by the narrow frog point and the load is not transferred to the wing rail until the frog point is passed. Theoretically, the drop from the frog point to the wing rail with a 1 in 20 tread having 5/16-in. chamfer is very near ¼-in. The result is damage to the frog point, as the concentrated wheel load is too great for the narrow section of metal at the point.

Even though the heavy taper is better from the standpoint of wheel-wear, in view of the fact that rail must be designed for the heaviest wheel-loads while the wheels are designed for a definite car capacity, it may be expedient to sacrifice some degree of service of wheel to favor the factor of safety and life of rail.

The very general use of taper of 1 in 20 makes the proposed departure from this standard a move needing to be fully substantiated by theory and practice. The use of 1 in 38 taper by the New York Central Railroad and the use of 1 in 13 taper by the Baltimore & Ohio, the former being flatter and the latter heavier than M.C.B. standard, represents some considerable difference of opinion.

In any change of taper it would appear desirable to have the taper uniform from the throat radius to the radius of the sand chill, or the full width of tread.

Thirty railroads, representing 95,000 miles, report use of canted tie-plates. Of these, four roads, with 15,000 miles, report that the rail is canted by adzing ties where canted tie-plates are not used.

Fourteen roads, with 52,900 mileage, report the general use of canted tie-plates.

Ten roads, with 32,900 mileage, report canted tie-plates used, but not generally.

Nineteen roads, with 55,000 mileage, report canted tie-plates with slope varying from 1 in 20 to 1 in 174 as follows:

Slope	1 in 20	115	miles	single	track
"	1 in 20 to 1 in 46	5	"	"	"
"	1 in 40	3344	"	"	"
"	1 in 43½ to 1 in 174	19	"	"	"
"	1 in 44	97	"	"	"
"	1 in 46	42	"	"	"
"	1 in 71	1	"	"	"
"	1 in 76	2418	"	"	"
"	1 in 80	6	"	"	"
"	1 in 80 and 1 in 86	64	"	"	"
"	1 in 83	1095	"	"	"
"	1 in 88	185	"	"	"
"	1 in 96	5	"	"	"
	Total	7396	"	"	"

Six roads of 23,000 miles have in use mechanical adzing and boring machines, which adze ties before being placed in track. (Only one of these roads use canted tie-plates and these have a taper of 1 in 76.)

A large number of measurements were carefully taken on one of the large railroads at at least 200 locations, both on curves and tangent, where the rail was wearing and showed a uniform wear and bearing on the rail-head. These measurements showed that for the rail of 2½-in. head, as well as rail of 3-in. head, both had a cant of 1 in 40.

From these general conditions above cited it would seem that if the rail was installed and maintained so as to provide a uniform bearing and wear on the head of rail, the best results would be obtained from both wheel wear and rail wear.

If the rail does not have the full and proper contact, as well as bearing on the tie-plates or on the tie, whether the tie-plates are canted or not, the best results cannot be secured.

Appendix D.

(5) REPORT ON SPECIFICATIONS FOR RELAYER RAIL FOR VARIOUS USES.

Your Committee submits herewith a proposed specification for relayer rail for various uses:

Main Track Relaying Rail:

Class 1.—Used rails suitable for main track or main or branch lines. They must be free from all physical defects and shall pass the A.R.E.A. Specifications for Steel Rail in all respects, except wear, as specified below. The surface of rails of this class must be fairly smooth and must not have flat spots or wheel burns. Side wear shall be measured at the gage line and vertical wear at the center of the head, and shall not exceed dimensions shown in table below. Rail must be sawed at the ends, not cut with chisel. Drilling must be uniform. Rails of this class may be further classified as follows:

Class 1—A: No side wear; top wear not to exceed 1/32-in.
1—B: Side wear not to exceed 1/8-in.; top wear not to exceed 1/16-in.
1—C: No side wear; top wear not to exceed 1/16-in.
1—D: Side wear not to exceed 1/4-in.; top wear not to exceed 1/8-in.
1—E: No side wear; top wear not to exceed 3/32-in.
1—F: Side wear not to exceed 3/8-in.; top wear not to exceed 3/16-in.
1—G: No side wear; top wear not to exceed 1/8-in.
1—H: Side wear not to exceed 1/2-in.; top wear not to exceed 1/4-in.

Resawing Rails:

Class 2.—All rails with battered or otherwise defective ends, which, if resawed, would meet the Class 1 requirements, will be accepted as resawing rails. These rails, when resawed, will be classed as "Main Track Relaying Rails." In this case 90 per cent. of the rail must be of uniform lengths, 27 ft. or more.

Side Track Relaying Rail:

Class 3.—All used rails suitable for side-tracks will be included in this class. They must not be less than 15 ft. long. Used or curve worn rails will be accepted if wear does not exceed 33 per cent. of the original section of head. Rails too badly line or surface bent to be included in Class 1, but straight enough to be easily spiked to line and gage.

Rails pitted or wheel-burnt, but still serviceable; rails with flow of metal, but still serviceable, will be accepted. Drilling must be uniform. Base must be full or uniform width.

Rolling Mill Rail:

Class 4.—Rails of standard section. Badly twisted or bent rails, frogs, switches and guard rails will not be accepted. They shall be not less than 6 ft. long. They must be free from pipes, split heads and similar defects.

Scrap Rail:

Class 5.—All used rails of any length or condition not meeting the above specifications, will be classed as scrap.

Marking and Shipping:

Rails of classes 1, 2, 3 and 4, when classified in track, shall be marked by painting the class number and letter in white on the web of the rail about 3 ft. from each end. No two classifications of rails shall be loaded on the same car.

Appendix E.

(7) CONSIDER DESIGN OF CUT TRACK SPIKES.

At the annual convention in March, 1916, your Committee recommended for consideration a design of cut spike (see Bulletin 183, pages 376-377) and fully set forth the various reasons why the design submitted should be adopted.

Although your Committee did not receive a single written criticism throughout the year of the proposed design, when it was presented for adoption at the 1917 convention the Association turned it back to the Committee because of the claim by members of the Association that manufacturers could not make this spike with automatic spike machines. This contention was further substantiated by representatives of certain manufacturers on the floor of the convention.

Unfortunately, neither the Chairman of your Committee, or any member of the Sub-Committee who had prepared the original design, were present to defend the Committee's position.

Your Committee advises that the standard spike of the Canadian Pacific Railway for the past ten years has been made with a reinforced neck, just as called for in the design submitted by your Committee in 1917. As a matter of information, we quote the following letter received from the Nova Scotia Steel & Coal Company, dated July 26, 1917:

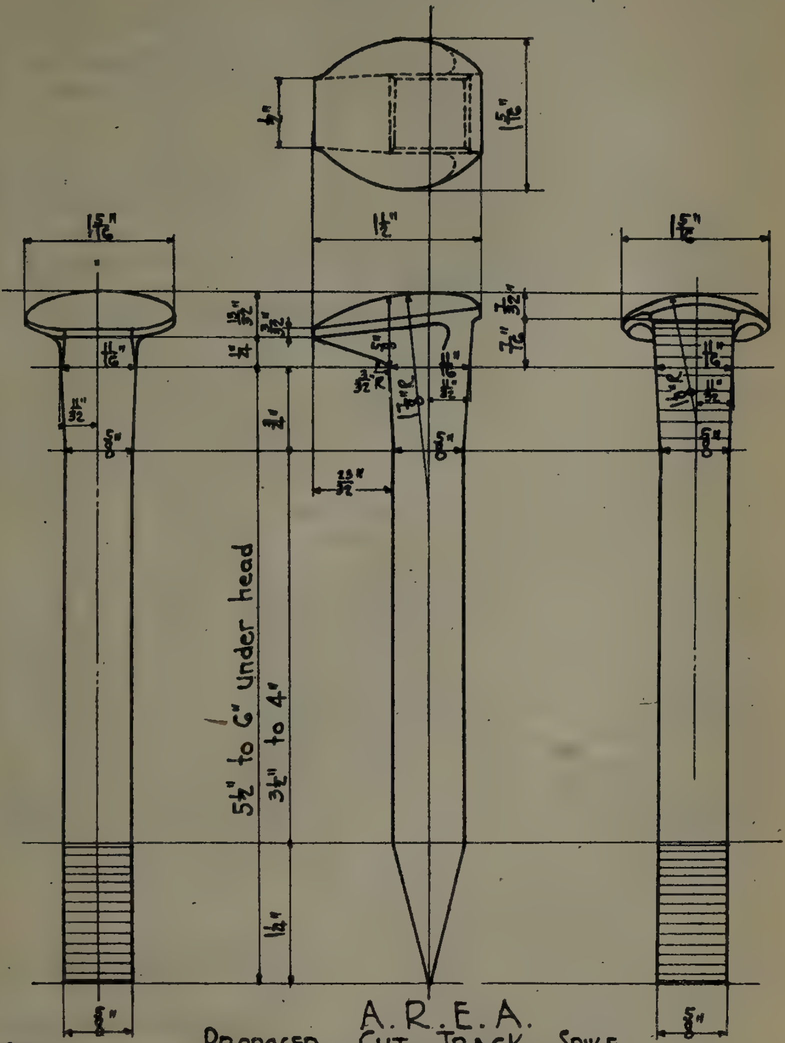
> "In reference to Track Spikes submitted to you by Mr. Fairbairn, of the Canadian Pacific Railway Company, and which have been criticized by the different manufacturers in your country as being impracticable to make on the automatic spike machines, principal objection being width and thickness of the neck, and thickness of the head. We may say in reply that for the past number of years we have been turning out spikes of this description in very large quantities from our automatic spike machines, and we have no difficulty in supplying spikes such as referred to you, and which is the Canadian Pacific Railway's standard."

Your Committee secured sample spikes during the past year from the Canadian Pacific Railway Company and found these spikes to conform to the Committee's specification in every respect.

In justice to the former Track Committee, we desire to state that the fact was fully developed by that Committee that the spike as recommended in 1917 was being manufactured on automatic spike machines in large quantities in two or three Canadian mills.

During the past season your Committee has made a careful canvass of several mills in the United States, and found a uniformity of opinion among the manufacturers that the standard as proposed by your Committee in 1917 cannot be made with automatic machines now in use. We understand that the main difficulty is overcome by the Canadian mills by using special rolled bars a little over-size in one dimension. We can see no reason why the same practice could not be utilized by United States mills. Nevertheless, on account of this general complaint, and because of the present war conditions, your Committee has decided to make a reduction in the amount of reinforcing under the head, and accordingly submit a revised design..

Mr. Wiltsee visited the Illinois Steel Mill at Joliet in September. The tests made by that company indicate that the design we now submit can be manufactured with the machines and shapes now in use.



A.R.E.A.
PROPOSED CUT TRACK SPIKE
Submitted by Sub-Committee No 5.
TRACK COMMITTEE 1917.

Exhibit
"C"

Appendix F.

(8) REPORT UPON THE EFFECT OF FAST TRAINS UPON THE COST OF MAINTENANCE OF WAY AND EQUIPMENT.

The economic value of a solution of this question depends upon the desirability of making each class of traffic bear its own proportion of the total expense of transportation.

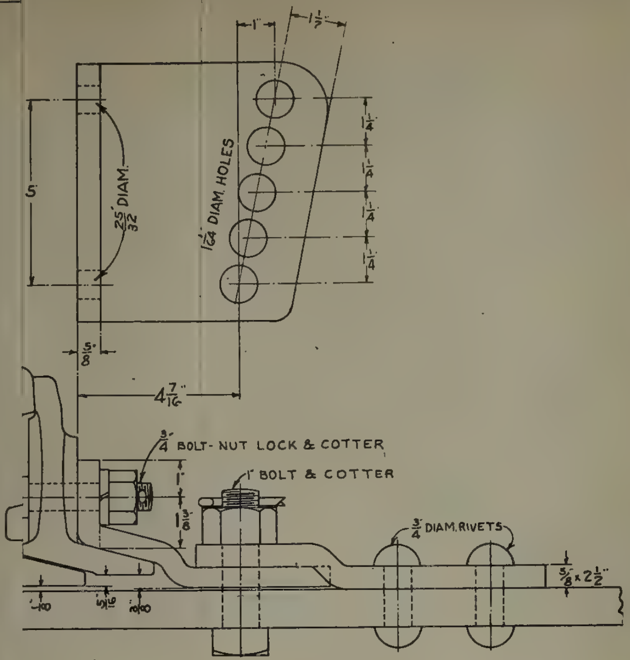
In the sense here used, traffic is classified not merely as between passenger and freight, but between the different classes of each kind of traffic grouped according to the speeds at which it is demanded that it be moved. It is unquestionably desirable, in so far as possible, to make each of these groups bear the expense incident to their use of the facilities furnished by the railroad, at least up to the point that any added expense would work a detriment to the welfare of the public as a whole.

In most cases, it is doubtful if it is desirable to carry on a class of business which is not able to pay its own way, but must share its burdens with business of another class, except temporarily, during a period of development of a class of business which promises later to be of economic value. It is therefore important that we know as nearly as possible the exact cost of the various kinds of business we carry on in order that each may carry its fair burden of expense.

In the expense accounts of railroads, as now kept, it is possible to segregate, as between freight and passenger, approximately 70 per cent. of the expense incurred by each class of traffic, but it is not possible under the present system of accounting to determine the relative cost of one part of either class of traffic as compared with any other. Of the 30 per cent. of the railroad expenses, which, under the present system of accounting, cannot be directly charged against freight or passenger, but must be charged in common against both, Maintenance of Way and Structures expense constitutes the major portion, so that if we are able to arrive at a definite relation of the cost of each of these classes of traffic to the other, or to the total, in so far as Maintenance of Way and Structures is concerned, we have made a long stride toward a definite solution of the problem before us.

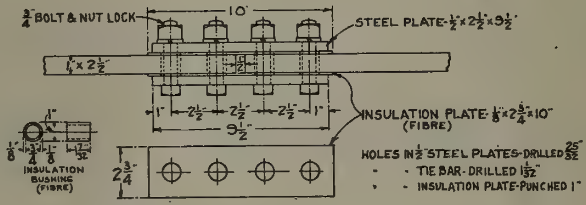
When we speak of high-speed traffic versus low-speed traffic, there immediately comes to the mind of the experienced railroad man, as well as the layman, passenger traffic versus freight.

The demands of a passenger traffic for a speed greater than that of the freight traffic is so emphatic and universal that we have acquired the habit of automatically thinking of passenger traffic when speaking of high-speed traffic, and of freight traffic when we speak of low-speed traffic, although there is a difference between the speed at which a very considerable part of the freight tonnage is carried as compared with that of the balance of it.



DETAIL (ALTERNATE)

SED STEEL ADJUSTABLE SWITCH LUG
& CONNECTIONS


3/4" BOLT & NUT LOCK
10"
STEEL PLATE- 1/2" x 2 1/2" x 9 1/2"
1" x 2 1/2"
1/2"
1"
2 1/2"
2 1/2"
2 1/2"
1"
9 1/2"
INSULATION PLATE 1/8" x 2 3/4" x 10"
(FIBRE)
HOLES IN 1/2" STEEL PLATES-DRILLED 25/32"
" " TIE BAR- DRILLED 1 1/32"
" " INSULATION PLATE-PUNCHED 1"
2 3/4"
1"
1/8"
3/4"
1/8"
7/32"
INSULATION BUSHING (FIBRE)

DETAIL OF INSULATION
FOR TIE BARS

ЅHICK ON EACH SIDE
WN ON PLAN OF
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EEN HEAD AND FLANGE.
WEEN OUTER BAR
E BAR PROJECTS .
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SHALL BE NOT LESS

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SED THROUGH THE
THE SWITCH RAIL
FOR ATTACHING
PS AS SHOWN ON
ITCH RAIL AND
N DIAMETER, AND
WEB EXCEPT WHERE
OF SWITCH LUGS, ETC.

D DESIGN, NOT LESS
SECURED BY BOLTS
METER.

GENERAL DETAILS
FOR
SPLIT SWITCHES
STYLE-"A"

Appendix F.

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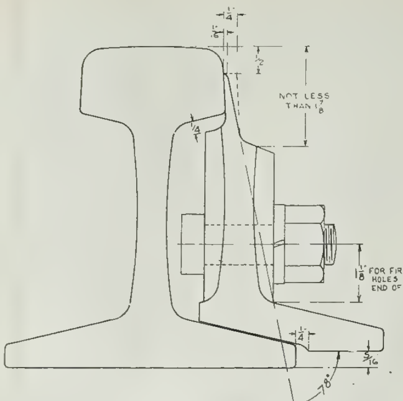
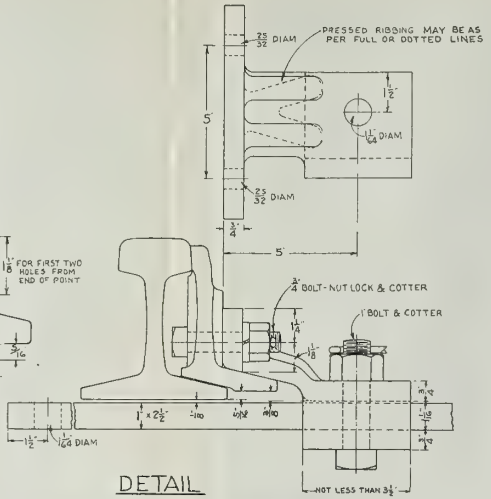
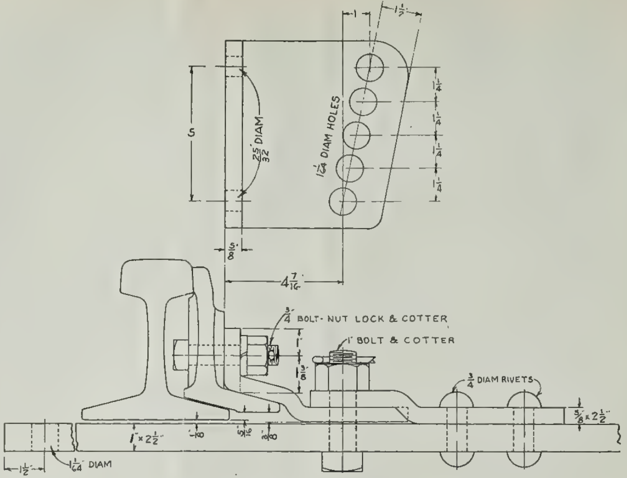


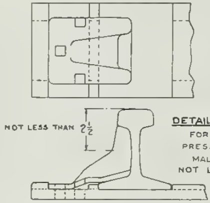
SECTION AT POINT
BEFORE ROUNDING



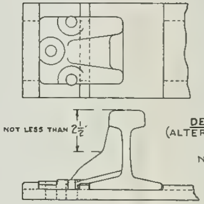
DETAIL
PRESSED STEEL SIDE JAW SWITCH LUG
& CONNECTIONS



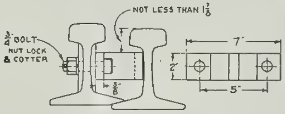
DETAIL (ALTERNATE)
PRESSED STEEL ADJUSTABLE SWITCH LUG
& CONNECTIONS



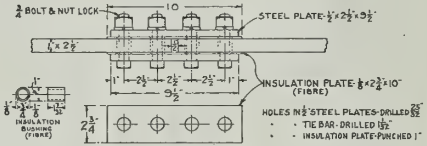
DETAIL OF RAIL BRACE
FOR CUT SPIKES.
PRESSED STEEL OR
MALLEABLE IRON
NOT LESS THAN ⅜" THICK



DETAIL OF RAIL BRACE
(ALTERNATE FOR SCREW SPIKES)
MALLEABLE IRON
NOT LESS THAN ⅜" THICK



DETAIL OF STOP


¾ BOLT & NUT LOCK
10
STEEL PLATE-½"x2½"x9½"
1"x2½"
½
1"
2½"
2½"
2½"
1"
9½"
INSULATION PLATE-⅛"x2¾"x10"
(FIBRE)
1"
⅛"
¾
⅛
7/32
INSULATION BUSHING (FIBRE)
2¾"
HOLES IN ½" STEEL PLATES-DRILLED 25/32"
" " TIE BAR-DRILLED 1 1/32"
" " INSULATION PLATE-PUNCHED 1"

DETAIL OF INSULATION
FOR TIE BARS

SWITCH POINT PLANING

TOP PLANING. ½" BELOW TOP OF STOCK RAIL AT POINT END, RUNNING OUT IN DISTANCE SHOWN ON PLAN OF SWITCH.

SIDE PLANING AND BENDING. SHALL CONFORM TO SPREAD BETWEEN THE GAUGE LINE OF THE STOCK RAIL AND THE SWITCH RAIL AS SHOWN ON PLAN OF SWITCH

PLANING, STOCK RAIL SIDE. SHALL CONFORM TO ANGLE OF HEAD OF STOCK RAIL SO THAT THE HEAD OF SWITCH RAIL SHALL FIT NEATLY AGAINST THE HEAD OF STOCK RAIL FROM THE POINT OF SWITCH RAIL TO THE POINT OF DIVERGENCE THE INNER EDGE OF THE HEAD OF STOCK RAIL AND THE OUTER FACE OF THE WEB OF SWITCH RAIL AT THE POINT SHALL BE IN THE SAME VERTICAL LINE WHEN THE SWITCH RAIL IS FITTED AGAINST THE STOCK RAIL.

PLANING, GAUGE LINE SIDE ORIGINAL CUT TO MAKE SWITCH POINT ¼" THICK AT END, ½" BELOW TOP OF STOCK RAIL ANGLE OF CUT WITH VERTICAL SHALL BE NOT LESS THAN 3°-35 (1/16" TO 1") OR TO SLOPE OF HEAD OF STOCK RAIL HAVING A GREATER ANGLE THAN THIS PLANING TO RUN OUT TO GIVE A STRAIGHT GAUGE LINE TO SWITCH RAIL

SECOND OR CHAMFER CUT TO MAKE SWITCH POINT 1/16" THICK, ½" BELOW TOP OF STOCK RAIL ANGLE OF PLANING SHALL BE 78° WITH HORIZONTAL, AND SHALL RUN OUT 2-0" FROM END. THE SWITCH POINT SHALL THEN BE GROUND TO A SHARP EDGE WITH A RADIUS OF 1½".

SWITCH POINT PLANING-(CONT'D)

BOTTOM PLANING. BOTTOM OF SWITCH POINT SHALL BE PLANED TO CLEAR BASE OF STOCK RAIL WHERE BASES OVERLAP, BY 1/32", AND SHALL CLEAR WEB OF STOCK RAIL BY AT LEAST ¼". BASE PLANING SHALL BE NOTCHED INTO BOTTOM OF SWITCH RAIL WHERE NECESSARY TO ALLOW A BEARING ON SWITCH PLATE TO ¼ CLEARANCE FROM SIDE OF FLANGE OF STOCK RAIL WHEN THE SWITCH RAIL IS FITTED AGAINST THE STOCK RAIL.

SWITCH RODS.

SWITCH RODS SHALL BE 1" THICK BY 2½ WIDE. BOLT HOLES SHALL BE 1 1/64" DIAMETER FOR TURNED BOLTS. THERE SHALL BE AT LEAST 1½" METAL AT THE END BEYOND BOLT HOLES. NO 1 ROD SHALL BE 6-6" LONG; NO. 2 ROD, 4-0" LONG; ADDITIONAL BACK RODS, WHERE CALLED FOR, SHALL EXTEND UNDER THE FLANGE OF THE STOCK RAIL AND SHALL BE 6'-0" LONG.

BOLTS AND NUTS.

ALL BOLTS THROUGH SWITCH RAILS, EXCEPT JOINT BOLTS, SHALL BE ¾ DIAMETER, WITH SQUARE HEAD, AND SHALL BE PROVIDED WITH HEXAGON NUTS, NUT LOCKS AND COTTERS. ALL BOLTS THROUGH SWITCH RODS TO BE TURNED BOLTS, WITH SQUARE HEADS, HEXAGON NUTS AND COTTERS.

REINFORCING BARS.

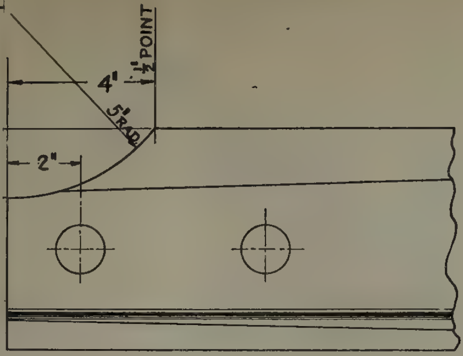
REINFORCING BARS SHALL BE ⅜" THICK ON EACH SIDE OF SWITCH RAIL AND OF LENGTH SHOWN ON PLAN OF SWITCH. REINFORCING BARS SHALL FIT AGAINST WEB OF RAIL AND SHALL FILL THE SPACE BETWEEN HEAD AND FLANGE THERE SHALL BE ¼ CLEARANCE BETWEEN OUTER BAR AND HEAD OF STOCK RAIL WHERE THE BAR PROJECTS UNDER THE SAME. TOP OF INNER BAR, WHERE IT PROJECTS BEYOND THE TOP OF SWITCH RAIL, SHALL BE NOT LESS THAN 1⅞" BELOW TOP OF STOCK RAIL

REINFORCING BARS SHALL BE FASTENED BY ¾" RIVETS OR BOLTS, EXCEPT BOLTS SHALL BE USED THROUGH THE FIRST EIGHT HOLES IN THE END OF THE SWITCH RAIL AND OTHER HOLES, WHERE PROVIDED, FOR ATTACHING ADDITIONAL SWITCH LUGS AND STOPS AS SHOWN ON SWITCH PLAN. HOLES THROUGH SWITCH RAIL AND REINFORCING BARS SHALL BE 13/16" IN DIAMETER, AND SHALL BE IN THE CENTER LINE OF WEB EXCEPT WHERE OTHERWISE SHOWN FOR ATTACHMENT OF SWITCH LUGS, ETC.

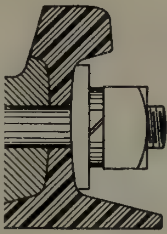
FOOT GUARDS.

FOOT GUARDS SHALL BE OF APPROVED DESIGN, NOT LESS THAN ⅜" IN THICKNESS, AND SHALL BE SECURED BY BOLTS OR RIVETS NOT LESS THAN ¾" DIAMETER.

GENERAL DETAILS
FOR
SPLIT SWITCHES
STYLE-"A"



ELEVATION OF POINT



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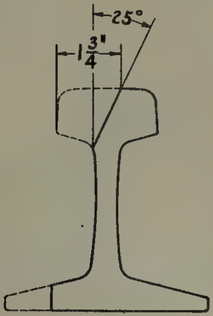
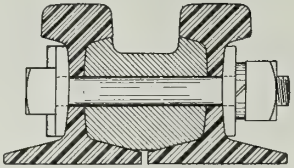
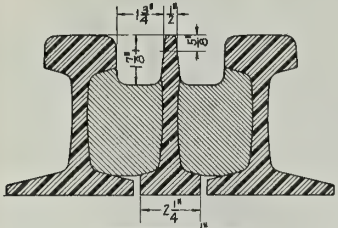


PLANING AT END
OF WING RAIL
FROG STYLE B

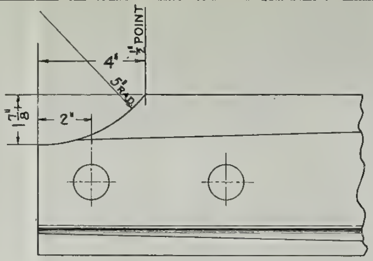
GENERAL DETAILS
FOR
RIGID FROGS
STYLES A AND B



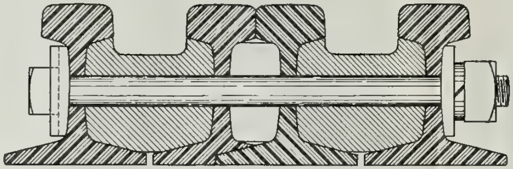
SECTION THROUGH THROAT BLOCK



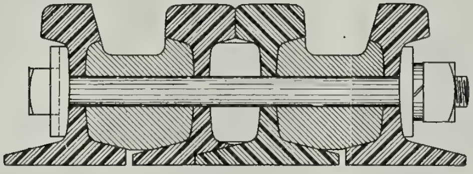
SECTION THROUGH ½" POINT



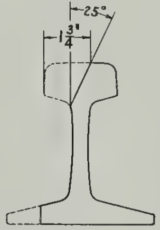
ELEVATION OF POINT



SECTION NEAR SEPARATION OF RAIL HEADS
FROG STYLE A



SECTION NEAR SEPARATION OF RAIL HEADS
FROG STYLE B



PLANING AT END
OF WING RAIL
FROG STYLE B

THROUGH BOLTS.

SHALL BE 1⅜" DIAMETER FOR RAILS, WEIGHING 120LBS PER YARD OR HEAVIER, THAT HAVE A FISHING SECTION OVER 3⅜" HIGH; NOT LESS THAN 1¼" DIAMETER FOR RAILS WITH A FISHING SECTION 3" HIGH AND OVER; 1⅛" DIAMETER FOR RAILS WITH A FISHING SECTION LESS THAN 3" HIGH, DOWN TO AND INCLUDING 80LB. RAILS. HEIGHT OF FISHING SECTION SHALL BE MEASURED ON VERTICAL CENTER LINE OF RAIL. ALL THROUGH BOLTS SHALL HAVE A DRIVING FIT. ALL THROUGH BOLTS SHALL BE OF HIGH TENSILE STEEL AND SHALL STAND COLD FLAT BEND TEST WITHOUT CRACK OR FRACTURE. ALL BOLTS SHALL HAVE SQUARE HEAD, SQUARE NUT AND U.S. STANDARD THREAD, AND SHALL BE PROVIDED WITH HEAD LOCKS, NUT LOCKS AND BEVELED WASHERS WHERE NECESSARY TO AFFORD A SQUARE BEARING. HEAD LOCKS AND BEVELED WASHERS SHALL BE NOT LESS THAN 3/16" THICK. SUITABLE WASHERS, NOT LESS THAN ½" THICK, SHALL BE PLACED UNDER THE NUTS TO BRING NUTS OUT FROM UNDER HEAD OF RAIL SO THAT THEY MAY BE TIGHTENED WITH AN ORDINARY WRENCH.

HEEL RISER BLOCKS.

HEEL RISER BLOCKS SHALL BE OF APPROVED DESIGN. THEY SHALL BE OF ROLLED, FORGED OR CAST STEEL, OR OF CAST IRON WITH ROLLED TEE STEEL WEARING SURFACE CAST INTEGRAL WITH SAME. WEARING SURFACE MUST BE EQUAL IN HARDNESS TO RAIL STEEL. HEEL RISER BLOCKS SHALL FIT THE SIDES OF THE HEADS AND SHALL HAVE PROPER BEARING ON THE BASE OF THE RAILS.

FILLER BLOCKS.

THROAT, WING AND POINT FILLER BLOCKS FOR FROG, STYLE A, AND THROAT FILLER BLOCK FOR FROG, STYLE B, SHALL BE OF GOOD QUALITY SOFT GREY IRON. BODY FILLER BLOCK FOR FROG, STYLE B, SHALL BE OF ROLLED STEEL. FILLER BLOCKS SHALL FIT THE FISHING ANGLES AND THE WEB OF RAIL FOR A DISTANCE OF ½" ABOVE AND BELOW THE BASE AND HEAD RESPECTIVELY, AND SHALL MAINTAIN THE REQUIRED FLANGEWAY.

RIVETS.

RIVETS THROUGH POINT RAILS SHALL BE ⅛" DIAMETER LESS THAN THE DIAMETER OF THE THROUGH BOLTS, AND MAY BE COUNTERSUNK AS SHOWN OR BUTTON HEAD, IN WHICH CASE, FILLER BLOCKS SHALL BE CUT OUT OR GROOVED TO FIT OVER SAME.

PLATES.

BEARING PLATES SHALL BE NOT LESS THAN ¾" THICK AND SHALL BE APPLIED TO GIVE A BEARING ON EACH TIE UNDER THE FROG WHERE THERE IS NOT SUFFICIENT SPREAD TO USE STANDARD SHOULDER PLATES. IF SEPARATE TIE PLATES ARE USED THEY SHALL BE NOT LESS THAN 7" WIDE. PLATES SHALL BE FLAT AND TRUE TO SURFACE AND ATTACHED TO FROG IN APPROVED MANNER SO AS NOT TO INTERFERE WITH TIGHTENING BOLTS.

LENGTHS.

LENGTH OF FROGS OVERALL SHALL NOT VARY MORE THAN ¼" FROM LENGTH SPECIFIED. WHERE FROG RAILS HAVE BEEN FIGURED TO CUT OUT OF FULL LENGH BARS WITHOUT WASTE A VARATION OF ½" SHALL BE ALLOWED IN THE WING RAILS AND LONG POINT RAIL. ANY VARIATION IN THE LENGTH OF THE WING RAILS MUST BE ON THE FLARED END; AND IN THE LONG POINT RAILS ON THE EXTENSION BEYOND THE ½" POINT.

GENERAL DETAILS
FOR
RIGID FROGS
STYLES A AND B

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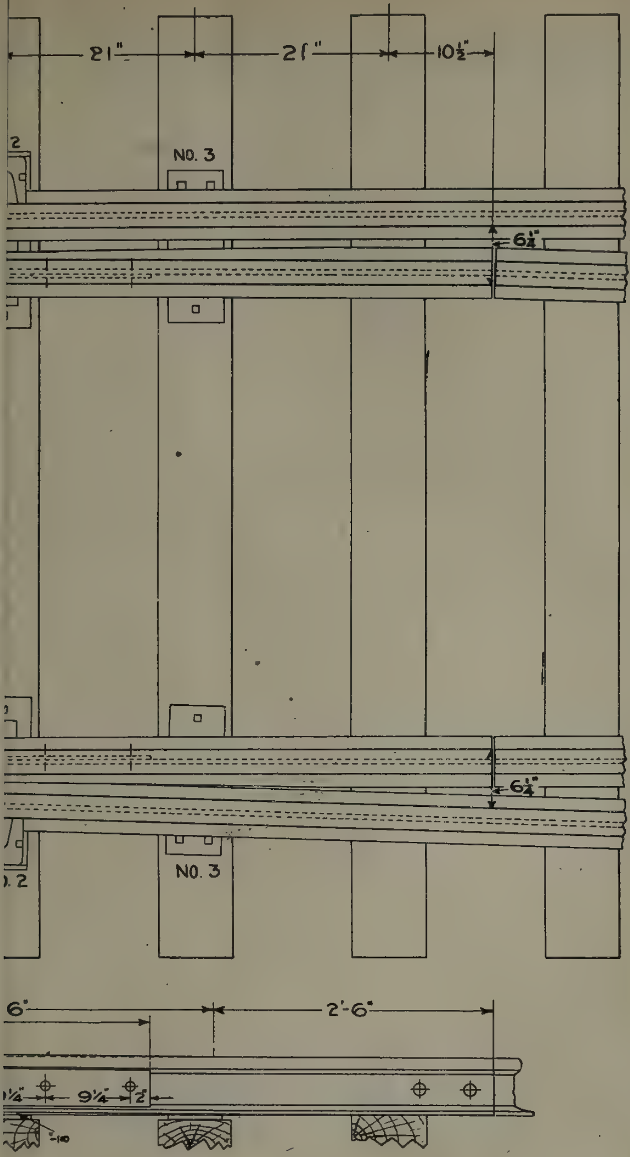

NOTES:-

STYLE "B" SWITCH FOR USE WHERE EQUIPMENT SPECIFIED FOR STYLE "A" SWITCH IS CONSIDERED HEAVIER THAN WARRANTED ON CLASS "B" OR CLASS "C" RAILWAYS; ALSO FOR EMERGENCY REQUIRMENTS.

FOR CLASSIFICATION OF RAILWAYS SEE PAGE 15, 1915 MANUAL.

FOR FURTHER DETAILS SEE SEPARATE PLAN.

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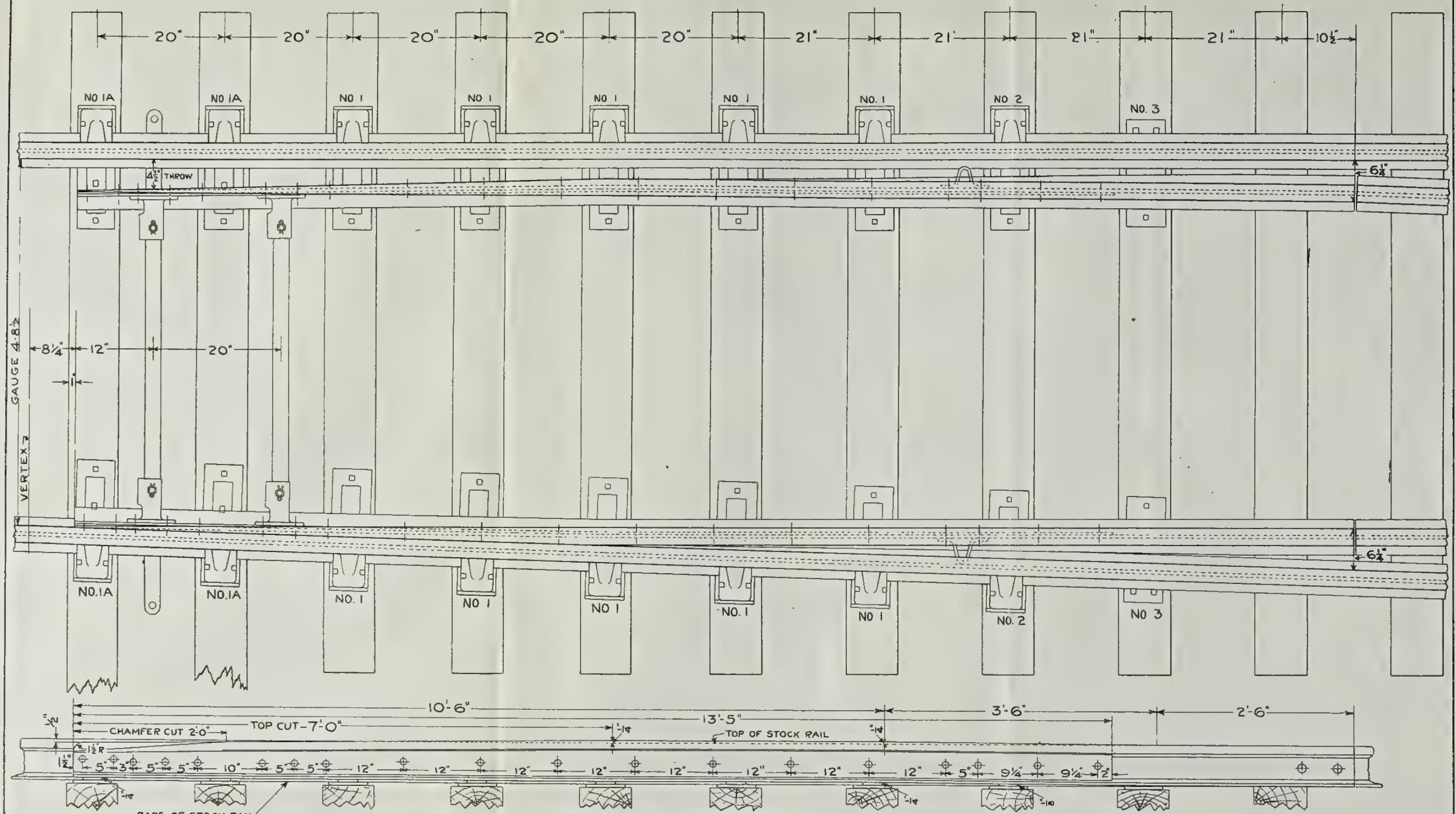


ELEVATION OF SWITCH POINT

16'-6" SPLIT SWITCH

ANGLE – 1°-44'-11"

STYLE - B

MATERIAL TO BE FURNISHED BY SWITCH & FROG MANUFACTURER FOR ONE SWITCH

2	REINFORCED SWITCH POINTS COMPLETE WITH SWITCH LUGS AND STOPS ATTACHED.
2	TIE BARS (No 1-6'6" LONG, No. 2-4'-0" LONG)
18	SWITCH PLATES (4#1A, 10#1, 2#2, 2#3)
16	BRACES

THROW AT	
HEAD ROD	END OF POINT
4¹¹⁄₁₆"	5"
* 4½"	4¹³⁄₁₆"
4¼"	4½"
4	4¼"
3¾"	4"

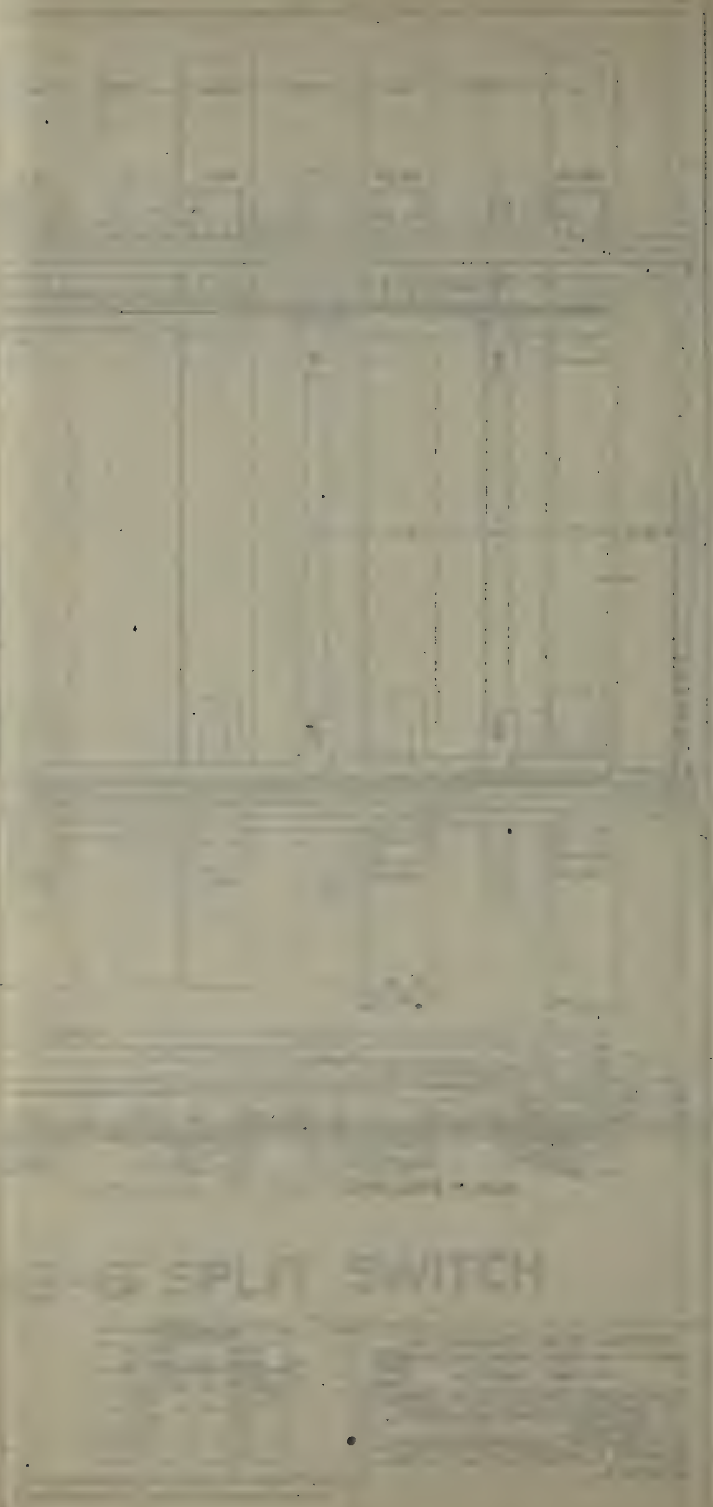
* 4½" THROW AT HEAD ROD RECOMMENDED. OR NOT GREATER THAN 5" OR LESS THAN 4" AT POINT

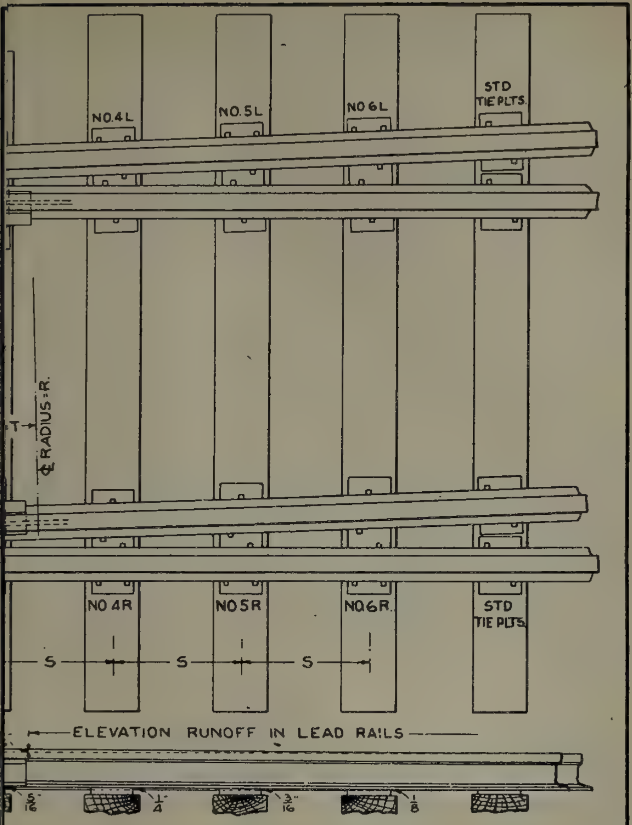
NOTES.-

STYLE "B" SWITCH FOR USE WHERE EQUIPMENT SPECIFIED FOR STYLE "A" SWITCH IS CONSIDERED HEAVIER THAN WARRANTED ON CLASS "B" OR CLASS "C" RAILWAYS; ALSO FOR EMERGENCY REQUIRMENTS.

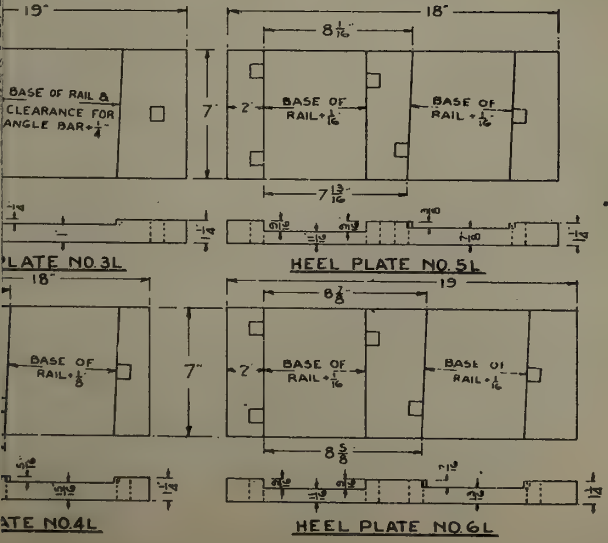
FOR CLASSIFICATION OF RAILWAYS SEE PAGE 13, 1915 MANUAL

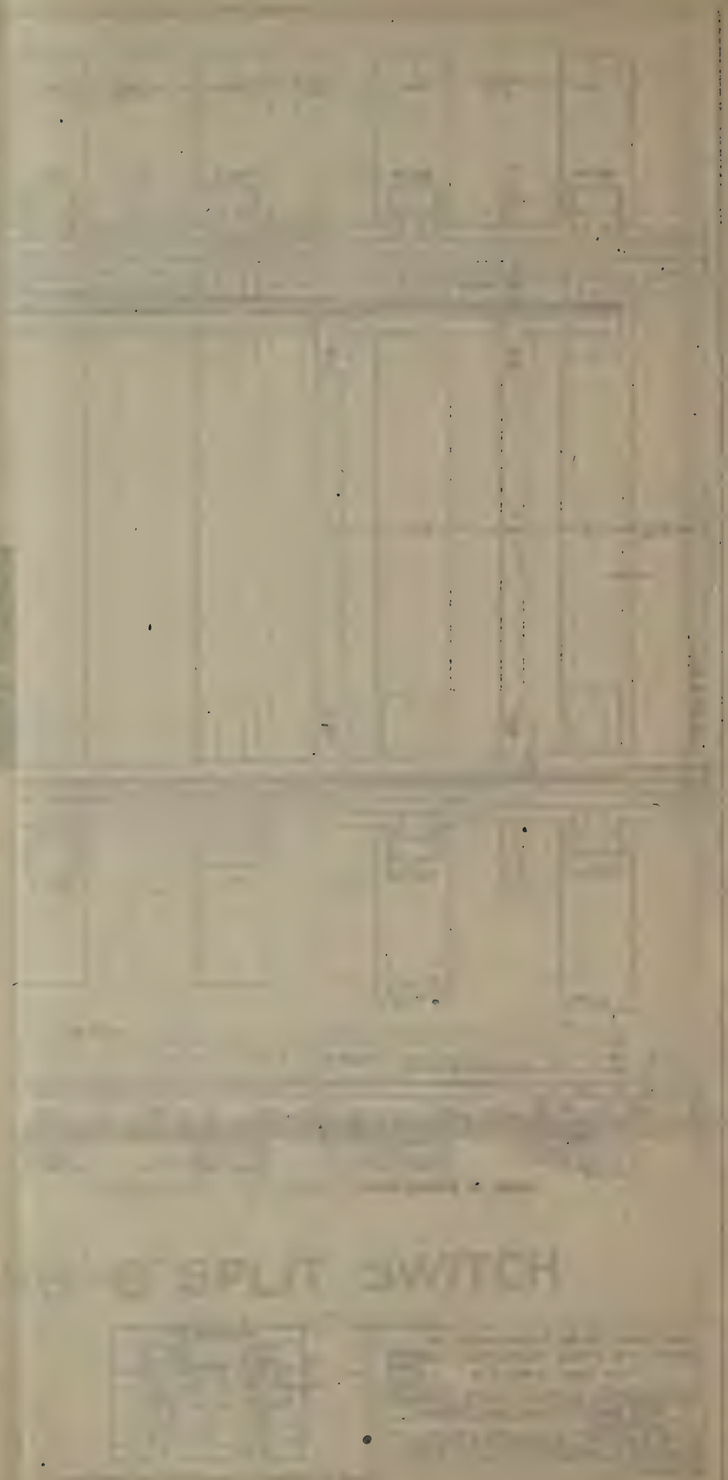
FOR FURTHER DETAILS SEE SEPARATE PLAN.

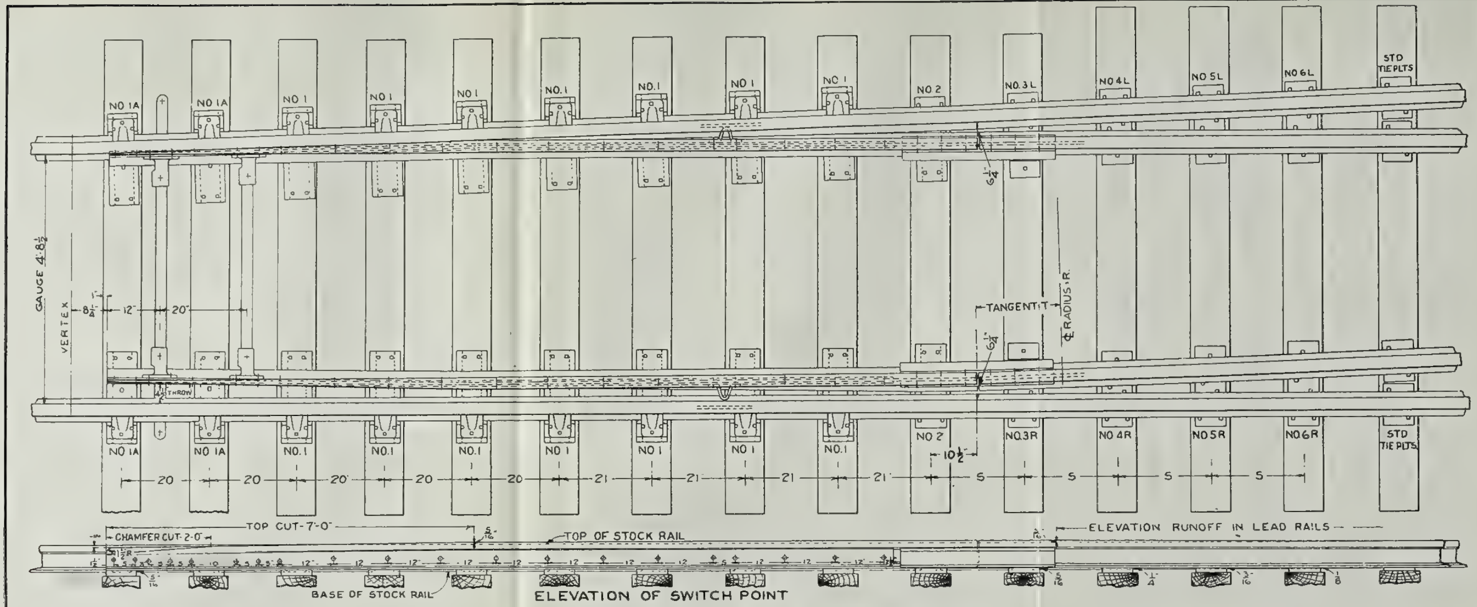

SPLIT SWITCH



FROG NO	TANGENT T	RADIUS R	TIE SPACING S
7	00	362.08'	19¼"
8	30	487.48	20
9	00	605.18'	20½"
10	00'	790.25'	21"




SPLIT SWITCH



THROW AT	
HEAD ROD	END OF POINT
4 11/16"	5"
* 4½"	4 13/16"
4¼	4½"
4	4¼"
3¾	4

* 4½ THROW AT HEAD ROD RECOMMENDED, OR NOT GREATER THAN 5" OR LESS THAN 4 AT POINT

16'-6" SPLIT SWITCH

ANGLE — 1°-44'-11"

STYLE - A

FROG NO	TANGENT T	RADIUS R	TIE SPACING S
7	00	36208	19¼
8	30	48748	20
9	00	60518	20½
10	00	79025	21

NOTES

RISERS ON SWITCH PLATES SHALL BE NOT LESS THAN 4" WIDE, OR THEY MAY BE THE FULL WIDTH OF THE PLATE DOTTED LINES INDICATE RISERS 4½ WIDE

HEEL PLATES SHALL BE MADE RIGHT HAND AND LEFT HAND, PLATES DETAILED ON PLAN ARE SHOWN LEFT HAND

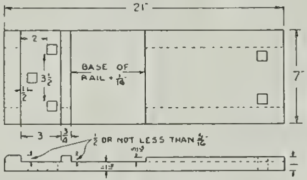
TWO PAIRS OF NO 1 PLATES SHALL BE PROVIDED WITH SPIKE HOLES, ¾"×1, FOR SPIKING SWITCHES IN CLOSED POSITION, AND SHALL BE MARKED NO 1A AS SHOWN ON PLAN

ALL HOLES FOR CUT SPIKES SHALL BE ¾" SQUARE UNLESS OTHERWISE SPECIFIED IF ⅞ SCREW SPIKES AND LAG SCREWS ARE USED, HOLES SHALL BE 15/16 DIA IN THE SAME LOCATION AS DETAILED FOR CUT SPIKES

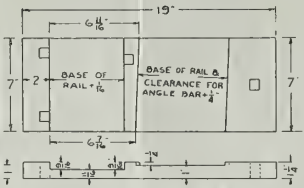
FOR FURTHER DETAILS, SEE SEPARATE PLAN

MATERIAL TO BE FURNISHED BY SWITCH & FROG MANUFACTURER FOR ONE SWITCH

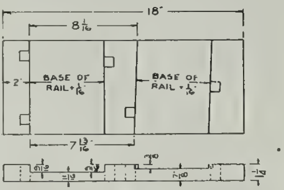
2	REINFORCED SWITCH POINTS COMPLETE WITH SWITCH LUGS AND STOPS ATTACHED
2	TIE BARS (NO 1-6'6" LONG NO 2-4'0" LONG)
28	SWITCH PLATES (4 #1A, 14 #1, 2 #2, 1 PR #3, 1 PR #4, 1 PR #5, 1 PR #6)
18	BRACES



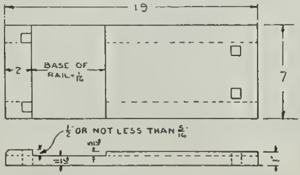
SLIDE PLATE NO 1



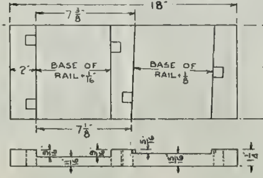
HEEL PLATE NO 3L



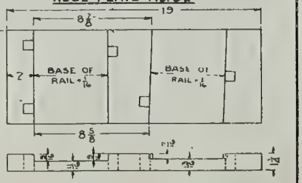
HEEL PLATE NO 5L



SLIDE PLATE NO 2



HEEL PLATE NO 4L



HEEL PLATE NO 6L

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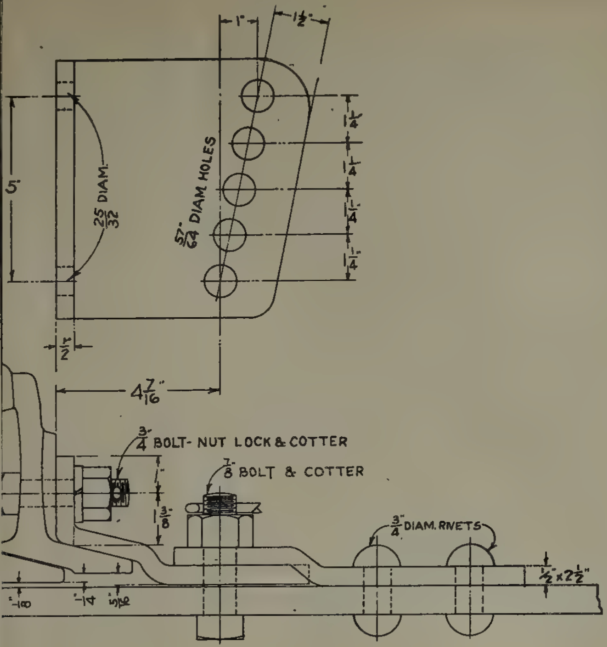

DETAIL (ALTERNATE)

SED STEEL ADJUSTABLE SWITCH LUG
& CONNECTIONS

BOLTS AND NUTS.
ALL BOLTS THROUGH SWITCH RAIL, EXCEPT JOINT BOLTS, SHALL BE 3/4" DIAMETER, WITH SQUARE HEAD, AND SHALL BE PROVIDED WITH HEXAGON NUTS, NUT LOCKS AND COTTERS. ALL BOLTS THROUGH SWITCH RODS SHALL BE TURNED BOLTS, WITH SQUARE HEADS, HEXAGON NUTS AND COTTERS.

REINFORCING BARS.
REINFORCING BARS SHALL BE 3/8" THICK AND PLACED ON GAUGE SIDE OF SWITCH RAIL, AND SHALL BE OF LENGTH SHOWN ON PLAN OF SWITCH. REINFORCING BARS SHALL FIT AGAINST WEB OF RAIL AND SHALL FILL THE SPACE BETWEEN HEAD AND FLANGE. TOP OF REINFORCING BAR, WHERE IT PROJECTS BEYOND THE TOP OF SWITCH RAIL, SHALL BE NOT LESS THAN 1 7/8" BELOW TOP OF STOCK RAIL.

REINFORCING BARS SHALL BE FASTENED BY 3/4" RIVETS OR BOLTS, EXCEPT BOLTS SHALL BE USED THROUGH THE FIRST EIGHT HOLES IN THE END OF THE SWITCH RAIL AND OTHER HOLES, WHERE PROVIDED, FOR ATTACHING ADDITIONAL SWITCH LUGS AND STOPS AS SHOWN ON SWITCH PLANS. HOLES THROUGH SWITCH RAIL AND REINFORCING BARS SHALL BE 13/16" IN DIAMETER, AND SHALL BE IN THE CENTER LINE OF WEB EXCEPT WHERE OTHERWISE SHOWN FOR ATTACHMENT OF SWITCH LUGS, ETC.

SWITCH PLATES.
SWITCH PLATES SHALL BE 5/8"x6" WITH PRESSED RISERS, OR ½"x6" WITH SOLID RISERS. SOLID RISERS SHALL BE NOT LESS THAN 3" WIDE, OR THEY MAY BE THE FULL WIDTH OF PLATE. DOTTED LINES INDICATE SOLID RISER 4" WIDE. TWO PAIRS OF NO.1 PLATES SHALL BE PROVIDED WITH SPIKE HOLES, 3/4" x 1", FOR SPIKING SWITCHES IN CLOSED POSITION, AND SHALL BE MARKED NO. 1A AS SHOWN ON PLAN OF SWITCH. ALL HOLES FOR CUT SPIKES SHALL BE 3/4" SQUARE, UNLESS OTHERWISE SPECIFIED.

FOOT GUARDS.
FOOT GUARDS SHALL BE OF APPROVED DESIGN, NOT LESS THAN 3/8" IN THICKNESS, AND SHALL BE SECURED BY BOLTS OR RIVETS NOT LESS THAN 3/4" DIAMETER.

25/32

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CLEAR WEB OF STOCK
INTO BOTTOM OF
SWITCH PLATE TO ¼"
IE SWITCH RAIL IS

IN ENDS OF No. 1 ROD
ES FOR SWITCH LUG
D BOLTS. THERE
HOLES. NO.1 ROD
BACK RODS, WHERE
RAIL AND SHALL BE

GENERAL DETAILS
FOR
SPLIT SWITCHES
STYLE-"B"

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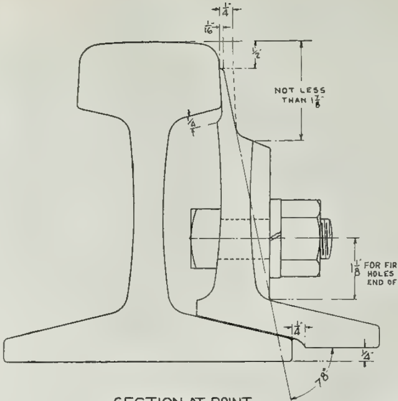
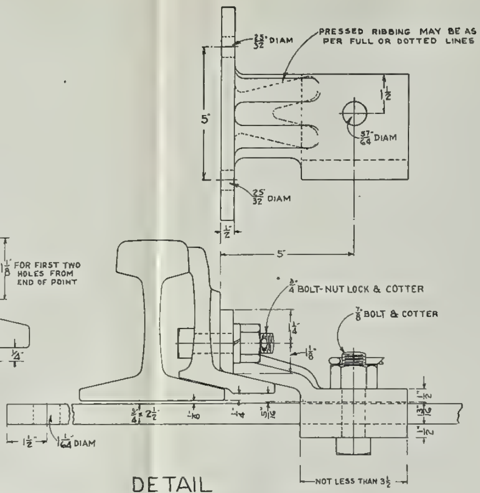
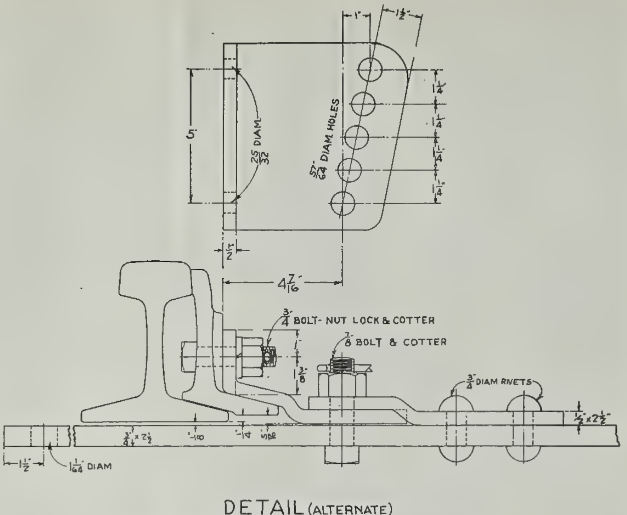


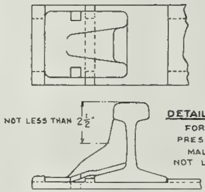
SECTION AT POINT
BEFORE ROUNDING


PRESSED RIBBING MAY BE AS PER FULL OR DOTTED LINES
25/32" DIAM
57/64" DIAM
¾" BOLT-NUT LOCK & COTTER
⅞" BOLT & COTTER
1 1/64" DIAM
NOT LESS THAN 3½"

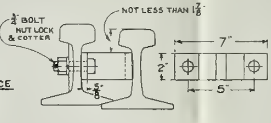
DETAIL
PRESSED STEEL SIDE JAW SWITCH LUG
& CONNECTIONS



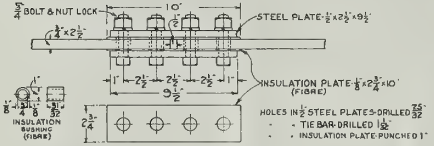
DETAIL (ALTERNATE)
PRESSED STEEL ADJUSTABLE SWITCH LUG
& CONNECTIONS



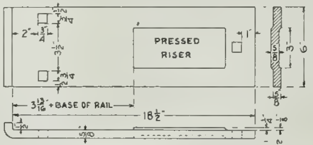
DETAIL OF RAIL BRACE
FOR CUT SPIKES
PRESSED STEEL OR
MALLEABLE IRON
NOT LESS THAN ⅜" THICK



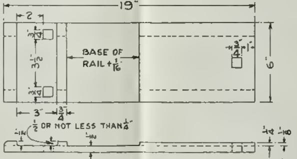
DETAIL OF STOP


¾" BOLT & NUT LOCK
STEEL PLATE-½"x2½"x9½"
INSULATION PLATE-⅛"x2¾"x10" (FIBRE)
INSULATION BUSHING (FIBRE)
HOLES IN ½" STEEL PLATES-DRILLED 25/32"
" TIE BAR-DRILLED 1 1/32"
" INSULATION PLATE-PUNCHED 1"

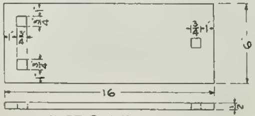
DETAIL OF INSULATION
FOR TIE BARS



SLIDE PLATES NOS. 1&2
(PRESSED RISER)



SLIDE PLATES NOS. 1&2
(WITH SOLID RISER)



SLIDE PLATE NO.3

SWITCH POINT PLANING.

TOP PLANING. ½" BELOW TOP OF STOCK RAIL AT POINT END, RUNNING OUT IN DISTANCE SHOWN ON PLAN OF SWITCH

SIDE PLANING AND BENDING. SHALL CONFORM TO SPREAD BETWEEN THE GAUGE LINE OF THE STOCK RAIL AND THE SWITCH RAIL AS SHOWN ON PLAN OF SWITCH

PLANING, STOCK RAIL SIDE. SHALL CONFORM TO ANGLE OF HEAD OF STOCK RAIL SO THAT THE HEAD OF SWITCH RAIL SHALL FIT NEATLY AGAINST THE HEAD OF STOCK RAIL FROM THE POINT OF SWITCH RAIL TO THE POINT OF DIVERGENCE. THE INNER EDGE OF THE HEAD OF STOCK RAIL AND THE OUTER FACE OF THE WEB OF SWITCH RAIL AT THE POINT SHALL BE IN THE SAME VERTICAL LINE WHEN THE SWITCH RAIL IS FITTED AGAINST THE STOCK RAIL.

PLANING, GAUGE LINE SIDE. ORIGINAL CUT TO MAKE SWITCH POINT ¼" THICK AT END, ½" BELOW TOP OF STOCK RAIL ANGLE OF CUT WITH VERTICAL SHALL BE NOT LESS THAN 3°-35 (1/16 TO 1) OR TO SLOPE OF HEAD OF STOCK RAIL HAVING A GREATER ANGLE THAN THIS. PLANING TO RUN OUT TO GIVE A STRAIGHT GAUGE LINE TO THE SWITCH RAIL.

SECOND OR CHAMFER CUT TO MAKE SWITCH POINT 1/16" THICK, ½" BELOW TOP OF STOCK RAIL. ANGLE OF PLANING SHALL BE 78° WITH HORIZONTAL, AND SHALL RUN OUT 2-0 FROM END. THE SWITCH POINT SHALL THEN BE GROUND TO A SHARP EDGE WITH A RADIUS OF 1½".

BOTTOM PLANING. BOTTOM OF SWITCH POINT SHALL BE PLANED TO CLEAR BASE OF STOCK RAIL WHERE BASES OVERLAP, BY 1/32", AND SHALL CLEAR WEB OF STOCK RAIL BY AT LEAST ¼" BASE PLANING SHALL BE NOTCHED INTO BOTTOM OF SWITCH RAIL WHERE NECESSARY TO ALLOW A BEARING ON SWITCH PLATE TO ¼" CLEARANCE FROM SIDE OF FLANGE OF STOCK RAIL WHEN THE SWITCH RAIL IS FITTED AGAINST THE STOCK RAIL.

SWITCH RODS.

SWITCH RODS SHALL BE ¾" THICK BY 2½" WIDE BOLT HOLES IN ENDS OF No 1 ROD SHALL BE 1 1/64" DIAMETER FOR TURNED BOLTS. BOLT HOLES FOR SWITCH LUG CONNECTION SHALL BE 57/64" DIAMETER FOR ⅞" TURNED BOLTS. THERE SHALL BE AT LEAST 1½" METAL AT THE END BEYOND BOLT HOLES. NO.1 ROD SHALL BE 6-6" LONG; NO.2 ROD, 4'-0" LONG, ADDITIONAL BACK RODS, WHERE CALLED FOR, SHALL EXTEND UNDER THE FLANGE OF STOCK RAIL AND SHALL BE 6'-0" LONG

BOLTS AND NUTS.

ALL BOLTS THROUGH SWITCH RAIL, EXCEPT JOINT BOLTS, SHALL BE ¾" DIAMETER, WITH SQUARE HEAD, AND SHALL BE PROVIDED WITH HEXAGON NUTS, NUT LOCKS AND COTTERS. ALL BOLTS THROUGH SWITCH RODS SHALL BE TURNED BOLTS, WITH SQUARE HEADS, HEXAGON NUTS AND COTTERS

REINFORCING BARS.

REINFORCING BARS SHALL BE ⅞" THICK AND PLACED ON GAUGE SIDE OF SWITCH RAIL, AND SHALL BE OF LENGTH SHOWN ON PLAN OF SWITCH. REINFORCING BARS SHALL FIT AGAINST WEB OF RAIL AND SHALL FILL THE SPACE BETWEEN HEAD AND FLANGE. TOP OF REINFORCING BAR, WHERE IT PROJECTS BEYOND THE TOP OF SWITCH RAIL, SHALL BE NOT LESS THAN 1⅞" BELOW TOP OF STOCK RAIL.

REINFORCING BARS SHALL BE FASTENED BY ¾" RIVETS OR BOLTS, EXCEPT BOLTS SHALL BE USED THROUGH THE FIRST EIGHT HOLES IN THE END OF THE SWITCH RAIL AND OTHER HOLES, WHERE PROVIDED, FOR ATTACHING ADDITIONAL SWITCH LUGS AND STOPS AS SHOWN ON SWITCH PLANS. HOLES THROUGH SWITCH RAIL AND REINFORCING BARS SHALL BE 13/16 IN DIAMETER, AND SHALL BE IN THE CENTER LINE OF WEB EXCEPT WHERE OTHERWISE SHOWN FOR ATTACHMENT OF SWITCH LUGS, ETC

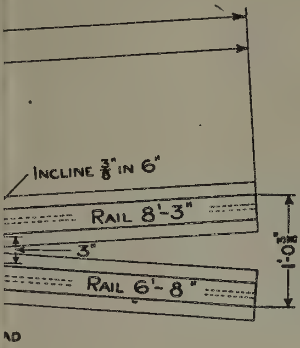
SWITCH PLATES.

SWITCH PLATES SHALL BE ⅝"x6" WITH PRESSED RISERS, OR ½"x6" WITH SOLID RISERS SOLID RISERS SHALL BE NOT LESS THAN 3" WIDE, OR THEY MAY BE THE FULL WIDTH OF PLATE. DOTTED LINES INDICATE SOLID RISER 4 WIDE. TWO PAIRS OF NO.1 PLATES SHALL BE PROVIDED WITH SPIKE HOLES, 3/4 x 1", FOR SPIKING SWITCHES IN CLOSED POSITION, AND SHALL BE MARKED NO.1A AS SHOWN ON PLAN OF SWITCH ALL HOLES FOR CUT SPIKES SHALL BE ¾ SQUARE, UNLESS OTHERWISE SPECIFIED.

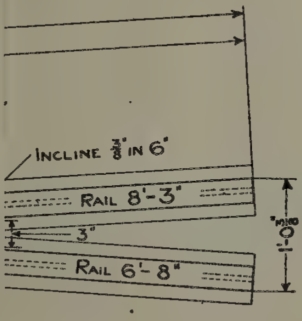
FOOT GUARDS.

FOOT GUARDS SHALL BE OF APPROVED DESIGN, NOT LESS THAN ⅜" IN THICKNESS, AND SHALL BE SECURED BY BOLTS OR RIVETS NOT LESS THAN ¾ DIAMETER.

GENERAL DETAILS
FOR
SPLIT SWITCHES
STYLE-"B"

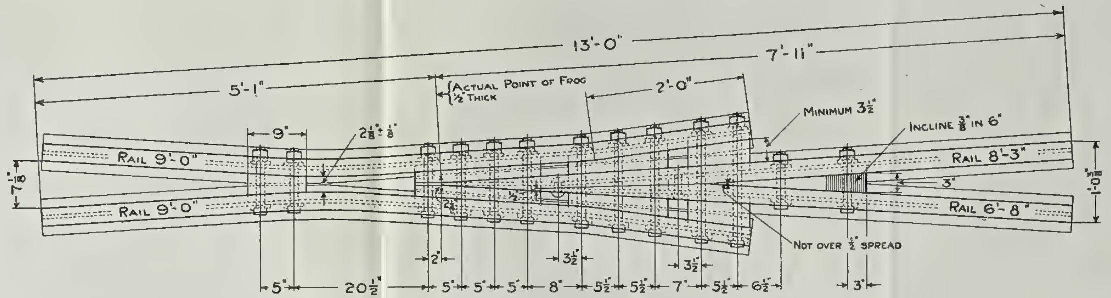


STYLE A

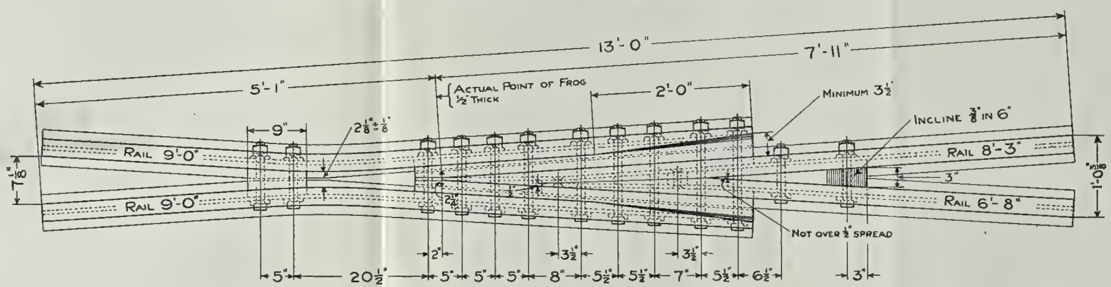


STYLE B

NOTE:-
FOR SECTIONS AND FURTHER DETAILS SEE SEPARATE PLAN.



STYLE A



STYLE B

NOTE:-
FOR SECTIONS AND FURTHER DETAILS SEE SEPARATE PLAN.

Nº 8 RIGID FROG

ANGLE 7°-09-10"

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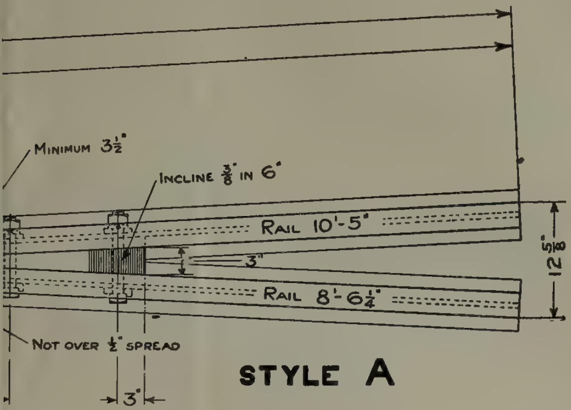
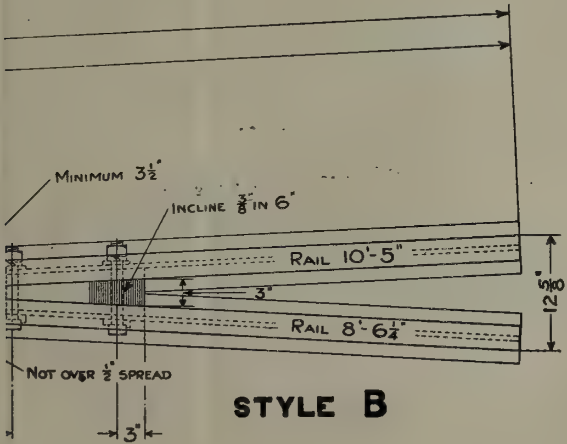


STYLE A



STYLE B

NOTE:-

FOR SECTIONS AND FURTHER DETAILS SEE SEPARATE PLAN.

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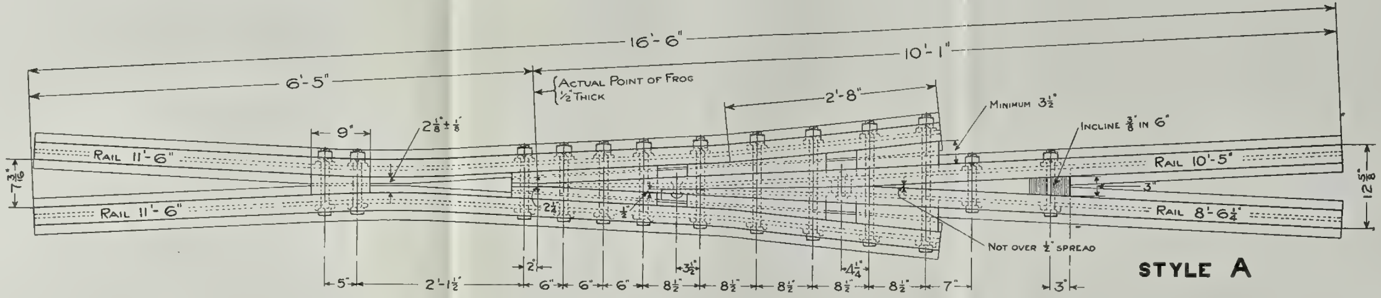
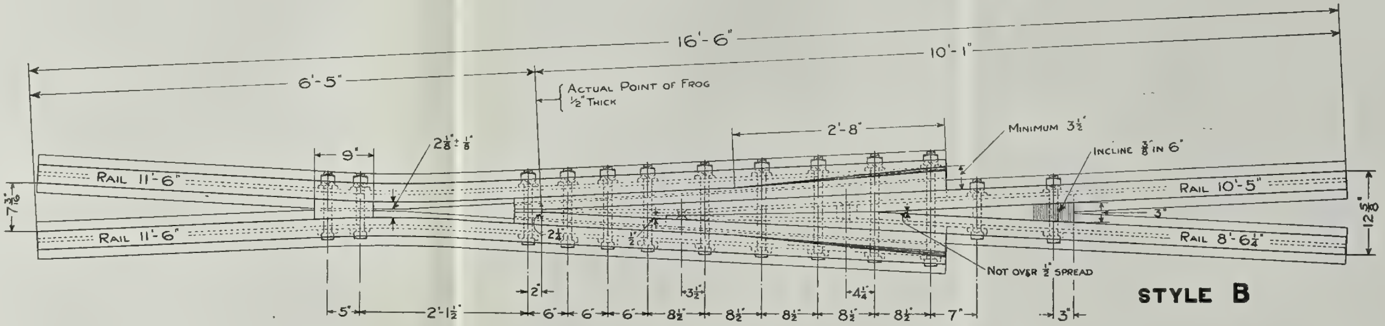


STYLE A

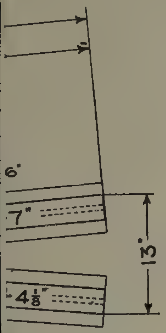


STYLE B

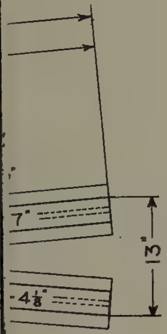
No 10 RIGID FROG

ANGLE 5°-43'-29"

NOTE:-
FOR SECTIONS AND FURTHER DETAILS
SEE SEPARATE PLAN.



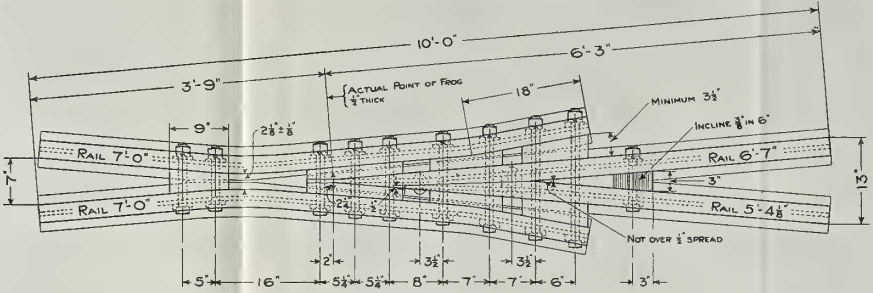
STYLE A



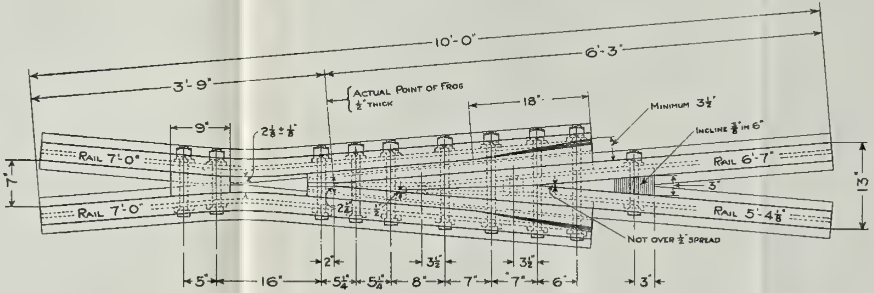
STYLE B

NOTE:-

FOR SECTIONS AND FURTHER DETAILS SEE SEPARATE PLAN.



STYLE A



STYLE B

NOTE:-
FOR SECTIONS AND FURTHER DETAILS
SEE SEPARATE PLAN.

Nº 6 RIGID FROG

ANGLE 9°-31'-38"

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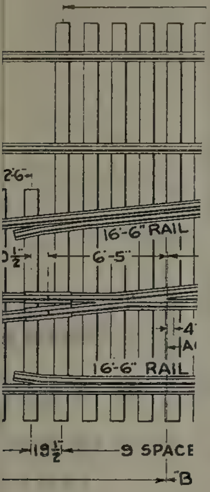
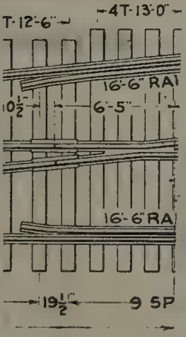


IO CROSSO'

'-6" TRACK TIE		
7"x9"-11'-0"	4PCS.	7
" 11'-6"	3 "	
" 12'-0"	3 "	
" " 12'-6"	3 "	



'URNOUT

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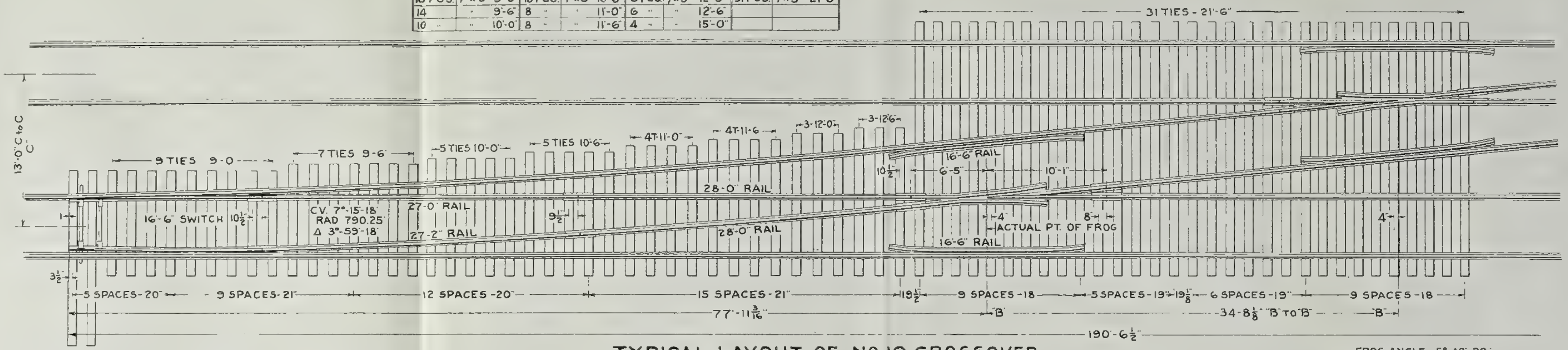
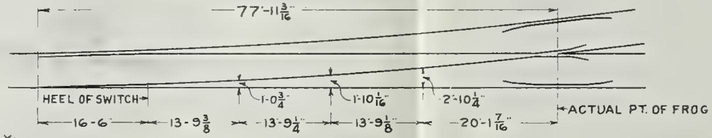
BILL OF TIMBER 8'-6" TRACK TIE 115 PIECES 8156' B/M							
18 PCS.	7"×9"-9'-0"	10 PCS.	7"×9"-10'-6"	6 PCS.	7"×9"-12'-0	31 PCS.	7"×9"-21'-6"
14	" 9'-6"	8 "	" 11'-0"	6 "	" 12'-6"		
10 "	" 10'-0"	8 "	" 11'-6"	4 "	" 15'-0"		



TYPICAL LAYOUT OF NO. 10 CROSSOVER

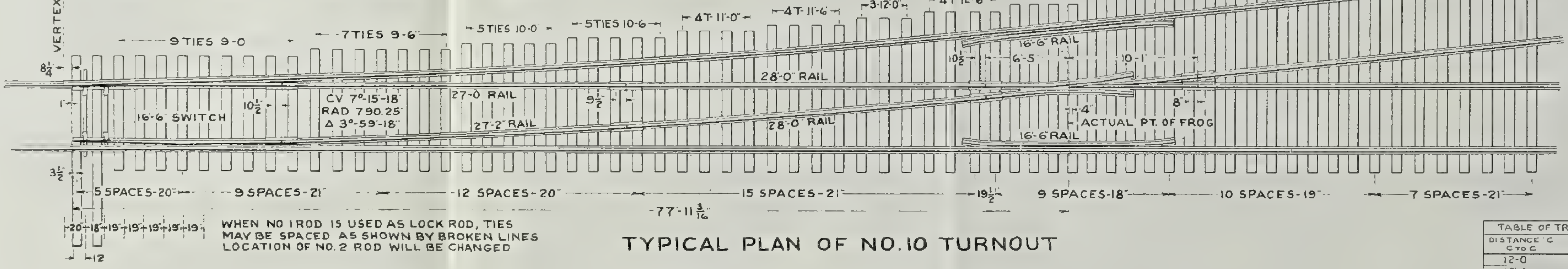
FROG ANGLE 5°-43'-29"
SWITCH POINT ANGLE 1°-44'-11"

OFFSET DIAGRAM



BILL OF TIMBER 8'-6" TRACK TIE 69 PIECES 4407' B/M							
9 PCS.	7"×9"-9'-0"	4 PCS	7"×9"-11'-0"	4 PCS	7"×9-13'-0"	5 PCS	7"×9"-15'-0"
7 "	" 9'-6"	4 "	" 11'-6"	3 "	" 13'-6"	3 "	" 15-6
5 "	" 10'-0"	3 "	" 12-0"	3 "	" 14'-0"	3 "	" 16-0"
5 "	" 10'-6"	4 "	" 12'-6"	3 "	" 14-6"	4 "	" 16'-6"

BILL OF TIMBER 8'-0" TRACK TIE 67 PIECES 4064' B/M							
9 PCS.	7"×9"-8'-6"	4 PCS	7"×9"-10'-6"	4 PCS	7"×9"-12'-6"	3 PCS.	7"×9"-14'-6"
7	" 9-0"	4 "	" 11'-0"	3	" 13'-0"	5 "	" 15'-0"
5 "	9-6"	3	" 11'-6"	3 "	" 13'-6"	3 "	" 15'-6"
5 "	" 10'-0"	4	" 12'-0"	3 "	" 14-0"	2 "	" 16-0"



TYPICAL PLAN OF NO. 10 TURNOUT

TABLE OF TRACK CENTERS	
DISTANCE "C" C TO C	DISTANCE "BB" BET. ACT FROG PTS.
12-0	24-8½
12'-6	29'-8 5/16"
13-0"	34'-8⅛"
13-6"	39'-8
14'-0"	44'-7⅞"
15-0"	54'-7½

CHANGE OF 1 FT IN DISTANCE "C"
CHANGES DISTANCE B-B 9-11 11/16" (9972)

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There are three general speed classifications:

First and lowest: Commodity freight tonnage.

Second and intermediate: Merchandise and perishable freight tonnage.

Third and highest: Passenger traffic or tonnage.

Many experiments and much experience contribute to general qualitative analysis of an expense incident to the graduations in speed, but not much is available from which definite quantitative conclusions can be drawn.

Your Committee does not feel that it is prepared to offer a conclusive report until it has given the matter further study. We have made an analysis of the actual expense for maintenance of way and structures for the year reported by the Interstate Commerce Commission's report of 1914 on all of the railroads in the United States having a gross earning of one and one-half million dollars and over. These roads comprise somewhat over 213,000 miles, so that averages deduced from this one year's experience may be taken as at least indicative of the real effect on maintenance cost of increasing speeds.

In this analysis, high speed and low speed are considered as synonymous with passenger traffic and freight traffic. Your Committee is conscious that this is not an entirely true assumption, but it offers the only opportunity for classifying the expense as incurred by the railroads in accordance with speed differences.

There are some expenses incident to the passenger traffic only, which are not affected by speed, such as the increased expense of buildings used for the conduct of passenger business over that used by freight, the beautifying of station grounds for passenger business beyond that which would be done if nothing but freight were handled, and a few other minor expenses. The main differences, however, between that incurred for passenger as compared to freight traffic is due to the higher standard of construction and maintenance required to handle with safety and expedition, the faster passenger trains as compared with the freight trains.

In making the analysis of the expenses, the car mile was chosen as the common unit of the two classes of traffic, on the assumption that it measured more nearly the facilities required by each class of traffic than any other. The car mile and train mile were the only two common units reported by the Interstate Commerce Commission and, taken as a whole, there would be a fairly definite relation maintained between these two units so that the conclusions drawn would not be materially different, whichever unit is chosen.

In making the analysis, a determination was made for each road; first, of the car miles per mile of road; second, the proportion of those car miles which were passenger car miles; third, the cost per mile of road for Maintenance of Way and Structures.

In order to eliminate two of these three variables, the roads were grouped into classes:

First, into groups of similar density of traffic, measured in car miles per mile of road.

Second, within each density group, roads of like per cent. of passenger traffic were segregated.

The total car miles on all roads of like density and like per cent. of passenger traffic was added, as was also the miles of road and the total cost of Maintenance of Way and Structures. The total miles of road was divided into the total car miles, so as to get an average density, and the total miles of road was divided into the total cost to arrive at an average cost per mile of road for each group of like density and like per cent. of passenger traffic.

From the tables thus produced, were picked out groups of like per cent. passenger traffic and different densities of traffic. These groups of like per cent. of passenger traffic were platted as shown in the accompanying diagram.

There were a few roads with no passenger traffic, or a very small per cent. These roads in many cases showed an unusually high cost of Maintenance of Way and Structures per thousand car miles of traffic. An investigation disclosed that roads doing this character of business in almost every case had abnormal expenditures due to an extraordinary percentage of miles of yard track per mile of road, as would be the case in a terminal railroad, or, an abnormal charge per mile of road for docks and wharves, as would be the case on the Duluth & Iron Range, or some other abnormal condition, and that the roads were therefore not comparable with the average railroad, so that in the plattings these roads were not used.

A separate line represents each of the various per cents. of passenger traffic to a horizontal scale of the average cost of Maintenance of Way and Structures per mile of road, and the vertical scale representing the density of traffic in thousands of car miles per mile of road.

Three lines only were platted, representing a passenger traffic of 7.5 per cent., 12.5 per cent. and 20.3 per cent. of the total traffic. These particular percentages were chosen because a sufficiently large number of roads could be obtained at these per cents. to produce more accurate plattings than of any other.

There are three factors which influence the cost of Maintenance of Way and Structures:

First, the elements, sometimes called weather stress.

Second, density of traffic.

Third, character of traffic, here separated as between passenger and freight.

There may be a fourth factor, i. e., the ability of the management to regulate the expenditures in strict accordance with the demand of the traffic. If there be this fourth factor, it will lose force or disappear entirely in the consideration of a large number of roads as is here done.

The three factors are disclosed by this chart, the weather stress being shown on the line of zero traffic, and has a different value for roads carrying different per cents. of passenger traffic as might be expected because of the different amount and character of material entering into the construction of the lines doing these different kinds of business.

The influence of increased density of traffic on roads carrying a given proportion of passenger traffic, is shown by all of the lines on the chart, showing an increased cost per mile of road with an increased density of traffic.

The factor of increased cost due to speed (when used synonymous with passenger versus freight) is shown by the decreased cost per mile of road for any given density of traffic for the smaller proportions of passenger traffic.

The Committee asks that this report be considered conclusive only in so far as passenger traffic versus freight traffic can be considered synonymous with fast speed versus low speed, and that the subject be referred back for further investigation and future report.

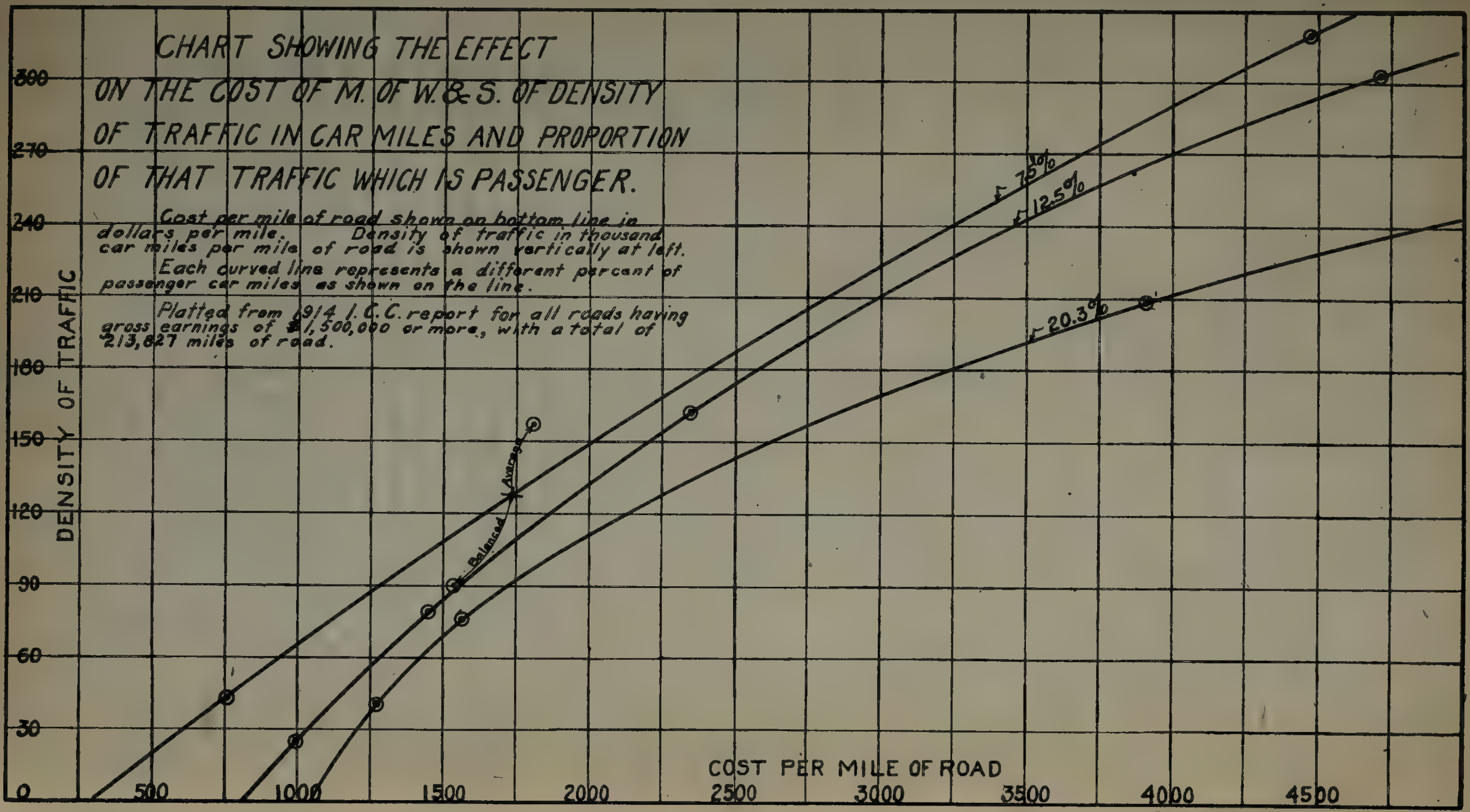

CHART SHOWING THE EFFECT ON THE COST OF M. OF W. & S. OF DENSITY OF TRAFFIC IN CAR MILES AND PROPORTION OF THAT TRAFFIC WHICH IS PASSENGER.

Cost per mile of road shown on bottom line in dollars per mile. Density of traffic in thousand car miles per mile of road is shown vertically at left.

Each curved line represents a different percent of passenger car miles as shown on the line.

Platted from 1914 I. C. C. report for all roads having gross earnings of $1,500,000 or more, with a total of 213,827 miles of road.

Appendix G.

(9) REPORT ON WHETHER WIDENING OF THE FLANGER OF THE WHEELS WOULD NOT BE DETRIMENTAL TO THE PRESENT STANDARD OF TRACK CONSTRUCTION.

Your Committee was requested by the Secretary to report to the Board on Subject (9) before the fall meeting of the American Railway Association. We submit herewith copy of a letter sent to the Secretary October 23, 1917:

"With reference to the subject assigned to the Association by the American Railway Association and referred to the Track Committee relative to contour of chilled car wheels, throat clearances for frogs, guard rails and crossings, effect of increase of thickness of wheel flanges, I beg to advise that at the last meeting of the Track Committee, held in Chicago, October 15, the Chairman was directed to send you the following communication:

"The Track Committee is willing to agree that the flanges can be increased, as recommended by the Chilled Car Wheel people, without any serious detriment from a track standpoint, provided:

"(1) That the wheels are in all cases accurately mounted to $\frac{3}{16}$-inch additional spread gage;

"(2) That the allowable flange wear before wheels are removed be changed so that wheels will be removed when the flange is worn to within $\frac{3}{16}$-inch of the present limit of removal;

"(3) That more care be used in matching wheels on any given axle on account of the reduction in play and the corresponding reduction in compensation from coning;

"(4) That this flange width be confined to flanges of four-wheel freight car trucks;

"(5) That this conclusion on the part of the Track Committee be not construed as an invitation to increase the axle load.

"With the above provisions, it is believed that it will be unnecessary to make any difference in the width of flangeway of frogs and crossings, or change the present method of track construction."

REPORT OF COMMITTEE XXII—ON ECONOMICS OF RAILWAY LABOR.

E. R. LEWIS, *Chairman;*	C. H. STEIN, *Vice-Chairman;*
W. J. BACKES,	C. B. HOYT,
R. A. BALDWIN,	C. M. JAMES,
J. Q. BARLOW,	W. A. JAMES,
A. F. BLAESS,	A. C. MACKENZIE,
W. M. CAMP,	THOS. MANEY,
H. M. CHURCH,	J. C. NELSON,
W. R. DAWSON,	C. A. PAQUETTE,
R. C. FALCONER,	J. W. PFAU,
R. H. FORD,	H. R. SAFFORD,
W. R. HILLARY,	H. J. SLIFER,
E. T. HOWSON,	

Committee.

To the American Railway Engineering Association:

Your Committee on Economics of Railway Labor respectfully submits its report to the nineteenth annual convention.

Your Committee was assigned the following subject by the Board of Direction:

"Study and report on the Economics of Railway Labor."

There is no subject of more importance to railway companies than labor. The increasing cost of living, and the removal from the American field of many thousands of workers from all walks of life for military duty, and of other thousands to war industries, only partially explains the present difficulties of employers. There is an unrest among men; there is a labor atmosphere surcharged with an energy which must be wisely directed to prevent dire calamity.

Thirty years ago this cloud was no larger than a man's hand. To-day it dominates the industrial world. America has profited by some of the errors of the Allies in preparations for war. Is there any reason why she should not profit by their industrial errors, to the end that the present labor situation may be turned to the advantage of the body politic, with the prevention of the results now openly prophesied by extremists and labor agitators? The interests which are represented by the membership of this Association have most at stake in this matter. The railroads of America form its greatest industry. They are of first importance to our civilization. They are the arteries which carry the life-blood of the nation. Therefore the Economics of Railway Labor is of paramount importance, not only to this Association, but to the nation at large, and therefore to the whole world in the present international crisis.

With this survey of the subject assigned, your Committee has undertaken the investigation of four phases believed to be most necessary to a thorough understanding of the railway labor problem of the day.

(1) BIBLIOGRAPHY.

Your Committee presents in Appendix A an indexed tabulation of publications each of which treats wholly or in part on some phase or phases of the Economics of Labor. This tabulation gives the name of the author, the title and date of the publication, and the shortest possible description for the guidance of the investigator.

(2) METHODS OF SECURING LABOR.

The primary importance of the advantages of thorough organization among railway companies of means to obtain labor is accentuated by the bidding against each other of employers in labor markets during the past season.

Manufacturers have been able to balance increasing labor costs by like increases in selling prices of products, whereas the railways could not at will increase the selling price of transportation. Nevertheless the manufacturers have organized labor-getting departments while the railways have so far made little advance along these lines. If the railways continue to pay lower wages than other employers, superior organization for obtaining railway labor must be made available.

High wages and high living go hand in hand. The high cost of living is in reality the cost of high living in the case of the laborer as in the case of the employer. In searching the field for means to retain labor, capital realizes the advantages of good feeding and good housing. Here, too, the railways experience various difficulties not presented to the manufacturer. Many men will not work where they cannot have the advantages of the settled community. Therefore it is of vital importance that the railways offer to labor reasonable living accommodations. Without them, labor cannot be hired, or, being hired, cannot be retained. And not being retained, the cost of the labor turnover threatens to far exceed the cost of the living accommodations required to reduce it to a level of true economy.

The report on this subject is given in Appendix B.

(3) FEEDING AND HOUSING OF MAINTENANCE OF WAY AND CONSTRUCTION EMPLOYES.

Your Committee presents its report on this topic in Appendix C.

(4) EQUATING TRACK SECTIONS.

Your Committee reports progress in compiling data based on the reports received from twenty railroads of the distribution of labor on seventy-six special track sections located as shown in Exhibit No. 1 of the report of the Track Committee, on page 433, Vol. 18, Proceedings for 1917. Two of these roads have reported discontinuing this report on account of insufficient force and abnormal conditions of labor.

Your Committee solicits increased co-operation from the membership in the collection of this data. There is nothing burdensome in the procedure, which is merely the setting down of the distribution of section labor in line with Interstate Commerce Commission requirements on forms supplied by this Association. The deductions are all made by the Committee. It is moreover vital to the success of this undertaking that continuous records be kept by all roads reporting, covering a certain period of years, in order that a composite diagram may be deduced, at the end of that period, of labor distribution typical of the period and of the roads concerned.

That conditions are abnormal does not seriously affect the comparative value of the information. It is probable, and indeed evident, that past conditions of labor will not recur; that what were normal conditions in 1915 may never be normal with conditions of the future. But your Committee's report is to be based essentially on comparisons of labor employment on roads in various geographical locations, maintained under various conditions of climate, traffic and track characteristics, covering one continuous period of years. Any condition affecting the whole country such as the present scarcity of men and resulting high wages due to the war, will not be a large factor in the comparative results desired. While it has been found impossible to tabulate reports received this season, it is hoped that full information will be available for presentation to the next convention.

COMMITTEE MEETINGS.

Meetings of the whole Committee were held in Chicago June 19th, September 11th, and October 30th, in addition to the meetings held by the various Sub-Committees.

CONCLUSIONS.

Your Committee recommends:

1. That the Bibliography, Appendix A, be accepted as information and printed in the Proceedings.
2. That the report on Methods of Securing Labor be accepted as information and printed in the Proceedings.
3. That the report on Feeding and Housing of Maintenance of Way and Construction Employes be accepted as information and printed in the Proceedings.

SUGGESTIONS FOR NEXT YEAR'S WORK.

1. Study and report on plans for organizations to obtain labor for railways.
2. Continue the study of Equating Track Sections.
3. Study and report on typical plans of boarding-cars and boarding-houses for railway laborers.

Respectfully submitted,

THE COMMITTEE ON ECONOMICS OF RAILWAY LABOR.

Appendix A.

(1) BIBLIOGRAPHY.

SUB-COMMITTEE.

A. F. BLAESS, *Chairman;*
W. M. CAMP.
H. M. CHURCH,
R. H. FORD,
W. A. JAMES,
H. J. SLIFER,

AMERICAN RAILWAY ENGINEERING ASSOCIATION.

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Railway Employes in the United States. Samuel McCune Lindsay.
  1901 Bulletin 37. U. S. Bureau of Labor.
    Gives wages and working hours of all classes of employes, including those on track and engineering work.

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Why Efficient Track Work is Skilled Labor. W. M. Camp.
  The advantage of skilled labor in Maintenance of Way Work. 2000 w.
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  Paper read before Roadmasters and Maintenance of Way Association.
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The excellent results of showing appreciation of good work are pointed out. 600 w.
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A study of the conditions which are working to attract men from railway service into other industries and advocating the employment of track men throughout the year. 800 w.
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The Wop in the Track Gang. D. T. Ciolli.
Exaggerated arraignment of conditions affecting unskilled track labor.
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Blames short-sighted policy of railroads for present labor conditions.
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Describes labor conditions encountered on the Canton-Hankau Ry.
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Material Prices Reflect Labor Conditions. Henry D. Hammond.
Discusses causes of price increases and their relation to the labor

situation. Concludes the present high prices are due largely to permanent causes. 1800 w.
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A resume of labor conditions in various parts of the country based upon letters from railway men in the labor centers. 4500 w.
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A discussion of the outlook for 1917, indicating an acute shortage.
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Engineering Methods must replace Paternalism in the Handling of Labor. Frances A. Kellor.
Scientific planning should be applied to industrial railway management and embrace whole field of employment, promotion and housing.
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Scarce Labor. Editorial.
Discussion of the situation produced by scarcity of labor. 600 w.
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Common Labor Hard to hold on job of track elevation, Rock Island finds.
Labor conditions on track elevation work near Chicago. Men stay on work on average of only 4.8 days, making work very costly.
Engineering News-Record, Vol. 78, p. 186; April 26, 1917. 1200 w.

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A detailed discussion of the shortage, the conditions leading up to it and methods of overcoming it. 6000 w.
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A discussion of the methods of hiring foreign labor and their working conditions, based on information developed by the United States Immigration Commission. 5000 w.
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  - An abstract of a committee report presented at the convention of the Roadmasters' Association. 2000 w.
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Two discussions of the characteristics of this class of men and their adaptability to track work. 4800 w.
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Three discussions of the serious disadvantages under which the railroads are now laboring and their methods of hiring men for track work. 5000 w.
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Massachusetts. Acts of 1906, Chap. 463, pt. 11, Section 179.
Requires railways employing any person who has to distinguish form or color signals to examine him for color-blindness or other defective sight. Penalty, $100.
See U. S. Bureau of Labor Statistics Bulletin 148, pt. 1, 952.

Alabama. Code of 1907, Section 5481.
Requires employes on railways to pass a thorough examination respecting capacity to fill position applied for, including examination for color-blindness and defective hearing. Penalty, $100 to $500.
See U. S. Bureau of Labor Statistics Bulletin 148, pt. 1, 153, 159.

Ohio. General Code, 1910, Section 12548.
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Physical Examination of Section Foremen. W. E. Schott.
A discussion of the difficulties following the arbitrary application of unnecessary requirements in the examination of these men. 500 w.
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Better Men for Track Work.
A discussion of the necessity for the employment of section foremen of a higher grade than formerly because of the increased demands which are now being made upon the track. 800 w.
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Maintenance of Way Foremen.

The Section Foreman Problem. Editorial.
A discussion of the importance of increasing the wages of section foremen. 400 w.
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A discussion of the scarcity of foremen and some of the reasons for this condition. 700 w.
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The Problem of the Section Foreman.
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Advocates the employment of track apprentices to provide material for section foremen. 900 w.
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A discussion of the handicaps under which railways are laboring in attracting the proper grade of men in track service. 900 w.
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Four discussions of the problem of securing an adequate supply of section foremen. 2000 w.
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A discussion of the responsibilities of this employe and the attention which should be given to his training. 2000 w.
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A comparison of conditions existing to-day with those two decades ago, with some constructive suggestions for improving the present situation. 700 w.
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A discussion of the principles underlying the organization of bridge and building gangs and the treatment of men to secure satisfactory results. 3500 w.
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Inadequate wages and the popular idea of the inferiority of the position are decreasing the number of candidates for this position. 1000 w.
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A discussion of some of the measures which are being adopted to elevate the position of section foreman and to attract a higher grade of men into that work. 900 w.
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Consider the Men We Have.
A discussion of the necessity of improving the conditions of foremen already in the service and training them to become more efficient.
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A detailed plan for the training of track employes for the position of foreman and a discussion of the improvement in working conditions which will be necessary. 4000 w.
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A discussion of some of the adverse living conditions encountered by men in this rank of railway service and their influence in leading men to other industries. 1000 w.
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A discussion of the qualifications which a successful track foreman must have. 600 w.
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A discussion of the necessary qualifications which a section foreman must possess before being promoted to a higher position. 1000 w.
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A discussion of the necessity for the employment of section foremen of a higher grade than formerly, because of the increased demands which are now being made upon the track. 800 w.
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Methods of procuring and keeping labor practiced by the B. & O., the two main features of which were the establishment of a labor bureau and the improvement of camping conditions. 900 w.
Engineering Record, Vol. 66, p. 569; November 23, 1912.

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Advocates the maintenance of a gang whose primary purpose would be the training of men for positions as track foremen. 700 w.
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The Foreman Problem. A. Schwartz.
A discussion of several methods of training men for this position.
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Description of two methods adopted by an eastern road to train men for the position of track foreman through the use of schools and positions as assistant foreman. 700 w.
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Job Finding and Man Hunting. Gibson Gardner.
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A discussion pointing out the objections to the turning over to the track forces of additional work now commonly handled by other branches of the Maintenance Department. 1500 w.
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Bleeding laborers by employment bureaus. Advocates Governmental control. 700 w.
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A discussion of the conditions confronting the Track Department in the maintenance of adequate forces with suggestions for the improvement of these conditions. 3000 w.
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What has been accomplished by public employment offices and what is needed to make them really efficient.
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A discussion of the effect of paying a higher rate for laborers on the supply for railway maintenance work. 500 w.
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A description of the method employed to secure track laborers by advertising in the want ad columns of the daily newspapers. 1600 w.
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A discussion of the benefits of a company-operated bureau for the employment of Maintenance of Way laborers. 800 w.
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Three discussions of the serious disadvantages which the railroads are now laboring under in their methods of hiring men for track work. 5000 w.
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A detailed discussion of the shortage, the conditions leading to it, and methods of overcoming it. 6000 w.
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A discussion of the difficulties of holding labor under present conditions. 800 w.
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Four discussions of means of overcoming the difficulties confronting the Maintenance of Way Departments in retaining an adequate force. 4500 w.
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A discussion of the conditions existing on a western road which prevents the railways from maintaining adequate forces. 1000 w.
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A discussion of the difficulties now being encountered by the railroads in holding an adequate force of carpenters in competition with the government and industries. 600 w.
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A discussion of the results which can be secured from cultivating this class of employes. 400 w.
Railway Age Gazette, July 21, 1911, p. 123.

Provisions for Maintaining Labor Supply on Railroad Work. Editorial.
Methods of procuring and keeping labor practised by the B. & O., the two main features of which were the establishment of a labor bureau and the improvement of camping conditions. 900 w.
Engineering Record, Vol. 66, p. 569; November 23, 1912.

Boarding Camps and Labor Shortage. Editorial.
A discussion of the adverse effect of the boarding camps ordinarily maintained in holding track labor. 800 w.
Railway Age Gazette, June 20, 1913, p. 1556.

Higher Efficiency Through Consideration for Labor. Editorial.
Advocates considerate and friendly treatment of laborers. 900 w.
Engineering Record, Vol. 68, p. 227; August 30, 1913.

Economics of Track Labor. H. R. Safford.
Abstract of an address delivered at the annual dinner of the Roadmasters' Association in which means of improving working conditions were emphasized. 2500 w.
Railway Age Gazette, September 19, 1913, p. 521.

Snaring the Bohunk. W. L. Amy.
How the man-catchers of the northwest lure the helpless laborer to intolerable conditions in the end-of-steel villages.
Advance Advocate, Vol. 22, p. 995-1000; October, 1913.

The Section Labor Problem. A. M. Clough.
Advocates better housing conditions for men. 1000 w.
Railway and Engineering Review, Vol. 53, p. 1041; November 8, 1913.

Suggested Means for Holding Laborers.
Practical suggestions for the removal of conditions which now tend to drive labor into other industries. 3500 w.
Railway Age Gazette, November 21, 1913, p. 979.

Sanitation of Camp Cars. Editorial.
A discussion of the possibility of state legislation to remove objectionable conditions in railway boarding camps. 300 w.
Railway Age Gazette, September 20, 1914, p. 956.

The Wop in the Track Gang. D. Ciolli.
An exaggerated arraignment of conditions affecting unskilled track labor. 2500 w.
Railway Review, Vol. 59, p. 373; September 16, 1915.

Holding Track Laborers. K. L. Van Auken.
Discusses methods of holding labor by good housing, feeding, good treatment, etc.
Railway Review, Vol. 57, p. 660, 663; November 20, 1915.

Holding Men. Editorial.
A discussion of the influence of living conditions on ability to hold men in service.
Railway Age Gazette, April 21, 1916, p. 894.

Competition for Designs for Railway Camps. Editorial.
General requirements for housing men on railway construction and maintenance work as considered by the National Americanization Committee of New York. 500 w.
Engineering News, Vol. 75, p. 819; April 27, 1916.

Holding Labor on Railroad Work.
Three discussions of the present shortage of labor with suggested

methods of living and working conditions as an aid in holding men in service. 4000 w.
Railway Maintenance Engineer, June, 1916, p. 169.

A Modern Boarding Car.
A description of the use of converted Pullman sleeping cars for the housing of floating carpenter gangs on the Bessemer & Lake Erie. 400 w.
Railway Maintenance Engineer, September, 1916, p. 260.

Housing Extra Gangs, Buffalo, Rochester & Pittsburgh Ry.
Railway Review, Vol. 59, p. 560-61; October 21, 1916.

Camp Equipment for Extra Gangs.
A description of the use of tents for floating gangs on the Buffalo, Rochester & Pittsburgh. 1200 w.
Railway Maintenance Engineer, November, 1916, p. 336.

Housing Men in Dismantled Box Cars. Editorial.
Advocates better housing of men. 600 w.
Railway Review, Vol. 59, p. 866; December 23, 1916.

Housing of Better Class Railroad Gangs Needs More Attention. J. T. Bowser.
Three plans showing how bridge and building and other maintenance men can be given better living quarters at low cost.
Engineering Record, Vol. 75, p. 94; January 20, 1917.

Housing and Caring for the Laborer. F. H. Rogers.
A description of an unusually complete camp installed by an eastern railroad in the vicinity of Philadelphia. 2000 w.
Railway Maintenance Engineer, March, 1917, p. 81.

Better Quarters for Workmen. Editorial.
Advocates better housing of men. 400 w.
Railway Review, Vol. 60, p. 388; March 17, 1917.

Engineering Methods Must Replace Paternalism in the Handling of Labor. Frances A. Kellor.
Scientific planning should be applied to industrial railway management and embrace whole field of employment, promotion and housing. 3500 w.
Engineering News-Record, Vol. 78, p. 82; April 12, 1917.

Laborers' Quarters by Joining Box Cars. Editorial.
Type of house for laborers. 300 w.
Railway Review, Vol. 60, p. 688, May 19, 1917.

Improvements in Housing Conditions. Editorial.
A discussion of the improved living conditions which a number of roads are now providing for their track laborers. 400 w.
Railway Maintenance Engineer, June, 1917, p. 171.

The Importance of the Boarding Camp. Editorial.
A discussion of the influence which the provision of proper food exerts on the retention of track men in service. 800 w.
Railway Maintenance Engineer, July, 1917, p. 205.

How Can We Keep Section Foremen?
A discussion of some of the adverse living conditions encountered by men in this rank of railway service, and their influence in leading men to enter other industries. 1000 w.
Railway Maintenance Engineer, July, 1917, p. 206.

Improving Railroad Boarding Camps.
Four discussions of the importance of this subject to the railways in holding an adequate force of laborers, with constructive suggestions for the design and construction of such camps. 9500 w.
Railway Maintenance Engineer, July, 1917, p. 207.

Better Housing Accommodations. Editorial.
A discussion of the necessity of providing better camps for the care of track laborers. 600 w.
Railway Maintenance Engineer, August, 1917, p. 237.

Better Housing of Maintenance Men.
Three discussions of improvements which can be made in camps for the use of Maintenance of Way men in an effort to retain them in the service. 7500 w.
Railway Maintenance Engineer, August, 1917, p. 251.

Providing Better Bunk Cars for Men.
A description of improved layouts which have been installed on several roads. 3500 w.
Railway Maintenance Engineer, September, 1917, p. 271.

Uplifting the Laborer.
Railway Review, Vol. 61, p. 263; September 1, 1917.

Improved Housing of Railway Employes.
Railway Review, Vol. 61, p. 295; September 8, 1917.

Application of Bonus System.

Another Angle of the Bonus System. Editorial.
A discussion of variations in the Bonus System as applied to track work. 400 w.
Railway Maintenance Engineer, August, 1917, p. 236.

Efficiency Awards for Crossing Watchmen.
A description of the Bonus plan which has been applied to crossing watchmen by the Lackawanna. 1000 w.
Railway Maintenance Engineer, September, 1917, p. 274.

Graduated Wages.

Variable Rates for Skilled Laborers. Editorial.
A discussion of the difficulty of holding a proper grade of men when all are paid a uniform rate. 300 w.
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Re-organizing the Gang. Editorial.
A discussion of the possibility of grading the wages of men in a gang according to experience as a means of retaining them in the service. 700 w.
Railway Maintenance Engineer, September, 1916, p. 328.

Prizes and Pensions.

The Prize System in Maintenance of Way Work.
A discussion of paper by E. A. Haskell, presented before Eastern Maintenance of Way Assn., entitled "Some Observations on the Methods and Results of Prize System in Maintenance of Way Work."
Railway Engineering Review, Vol. 42, p. 577; August 3, 1902.

United States Bureau of Labor.
Pension funds for municipal employes and railroad pension system of the United States. Prepared under the direction of Chas. P. Neill, Commissioner of Labor, Washington, Government Printing Office, 1910.
69 pages, 6°. (61st Cong. 2nd Sess. Senate Doc. 427.)

Rock Island Premiums for Efficiency of Roadmasters and Section Foremen.
An announcement of the distribution of premiums for efficiency in track work.
Railway Age Gazette, April 7, 1911, p. 830.

Bonus, Profit Sharing—Pensions. Waldron H. Rand.
A brief description of various schemes of business enterprises. 4500 w.
Journal of Accountancy, November, 1911.
Prize Systems in Track Work.
A description of the methods used on different roads to award prizes in recognition of excellence in track work. 2000 w.
Railway Age Gazette, February 16, 1912, p. 305.
Pension System. E. H. Hite.
M. K. & T. Employes' Mag., Vol. 1, p. 28-30; August, 1913.
Old Age Pension Schemes in the United States.
An unofficial list compiled by the Bureau of Labor Statistics, 1916. Six typewritten pages.
Pension System of Buffalo, Rochester & Pittsburgh Ry. Co.
Gives twice the amount paid by most roads.
Railway Age Gazette, Vol. 60, p. 171; January 28, 1916.
Change in Method of Determining Pensions on the Pennsylvania.
Railway Age Gazette, Vol. 62, p. 281; February 16, 1916.
Rock Island Pension System.
Railway Age Gazette, Vol. 60, p. 409; March 3, 1916.
Pensions on the Florida & East Coast.
Railway Age Gazette, Vol. 61, p. 37; July 7, 1916.
The Pension System and a Strike on the Southern Pacific.
Railway Age Gazette, Vol. 61, p. 143-144; July 28, 1916.
J. J. Hill Memorial Pensions, Great Northern Ry.
Railway Review, Vol. 59, p. 391; September 16, 1916.
The B. & O. Pension Plan. Wm. H. Ball.
B. & O. Employes' Mag., Vol. 4, p. 7-14; November, 1916.
Insurance—An Aid to Efficiency.
Union Pacific directors adopt a comprehensive scheme for life, accident and sickness protection for 40,000 employes.
Annalist, Vol. 8, p. 804; December 23, 1916.
Union Pacific Insures Employes.
Railway Age Gazette, Vol. 61, p. 1209; December 29, 1916.
Change of Method in Computing Service Pensions on the Penna. R. R.
Economic World, Vol. 99, p. 279, February 24, 1917.

Piece Work.

Use of Piece Work System on Jamaica Government Railway. Frank Richmond.
A description of the manner in which piece work is applied to the maintenance of roadway and structures on the Jamaica Railways with unit rates.
Railway Age Gazette, October 18, 1912, p. 751.

Continuous Employment.

Steady Employment for Track Men. Editorial.
Discusses desirability of maintaining gangs all the year. 1500 w.
Railway and Engineering Review, Vol. 53, p. 600; June 21, 1913.
A Permanent Track Maintenance Force on the Long Island R. R.
Excellent results in keeping men by organization of permanent forces. 1000 w.
Engineering News, Vol. 73, p. 474; March 11, 1915.
The Permanent Track Organization on the Long Island. G. P. Williams.
A description of the system by which track laborers are employed throughout the entire year. 2000 w.
Railway Age Gazette, January 21, 1916, p. 120.

The Labor Problem.
The study of the conditions which are working to attract men from railway service into other industries, and advocating the employment of track men throughout the year. 800 w.
Railway Maintenance Engineer, September, 1916, p. 259.

Holding Track Labor. E. A. Easley.
A plea for the re-arrangement of track work to enable a larger proportion of the forces to be employed throughout the year. 600 w.
Railway Maintenance Engineer, October, 1916, p. 294.

The Seasonable Distribution of Forces.
Abstract of a committee report presented to the Roadmasters' Association pointing out the opportunity for the extension of the working season in many classes of track work. 3500 w.
Railway Maintenance Engineer, October, 1916, p. 312.

Track Work in Winter.
Advocates winter track work as a method of holding labor. 700 w.
Railway Review, Vol. 59, p. 557; October 21, 1916.

Conserving Labor. Editorial.
A discussion of the necessity of extending the working season over as many months as possible in order to complete the necessary work with the forces available. 700 w.
Railway Maintenance Engineer, March, 1917, p. 68.

Solving the "Labor Turnover" Problem.
An appeal for the more intelligent employment of labor throughout the year. 1300 w.
Railway Maintenance Engineer, September, 1917, p. 280.

METHODS OF REDUCING MAINTENANCE OF WAY LABOR REQUIREMENTS.

Labor Saving Devices.

Power-Driven and Labor-Saving Appliances for Track Work.
Committee report of Roadmasters' and Maintenance of Way Association. Describes the operation of various devices. 1500 w.
Railway and Engineering Review, Vol. 53, p. 963; October 11, 1913.

Substitution of Mechanical Devices for Hand Labor in Track Work. Editorial.
Discussion of results obtained by labor-saving devices. 1000 w.
Railway Review, Vol. 60, p. 843; June 16, 1917.

Handling Rails by Power in Relaying.
Description of machines used in relaying rail. 600 w.
Railway Review, Vol. 60, p. 918; June 30, 1917.

Power-Driven Tools for Tamping Track.
Railway Review, Vol. 61, p. 175 and 211; August 11, 1917.

Labor Saving in Track Work.
Railway Review, Vol. 61, p. 205; August 18, 1917.

Efficient Organization of Maintenance of Way Work.

A Method for Standardizing Maintenance of Way Forces. H. W. Church.
Advocates establishing standard unit of work and organization to facilitate distribution of money for maintenance work. 3000 w.
Railway and Engineering Review, Vol. 45, p. 162; March 18, 1905.

Classifying Track Work Between Skilled and Unskilled Labor. Editorial.
Discusses the possibilities of giving special training to certain groups of men to prepare them for foremen's positions. 400 w.
Railway Age Gazette, July 21, 1911, p. 124.

Roadmasters' Efficiency Competition.
Six contributions received in a contest on this subject, describing

various ways of increasing the output of labor. 4500 w.
Railway Age Gazette, July 21, 1911, p. 129.

The Function of the Extra Gang. A. Swartz.
A discussion of the organization of this class of maintenance employes. 600 w.
Railway Age Gazette, August 18, 1911, p. 327.

Maintenance of Way Efficiency.
Four discussions of the manner in which greater returns can be secured from the labor employed. 3000 w.
Railway Age Gazette, August 18, 1911, p. 341.

Efficiency in the Maintenance Department.
Three discussions of means to secure better results from the labor employed. 2000 w.
Railway Age Gazette, October 20, 1911, p. 795.

Efficiency Methods in the Maintenance of Way Department of the Erie R. R.
A system providing close supervision, conduct of work by schedule, and standardization of detail operation.
Engineering Record, Vol. 64, p. 485; October 21, 1911.

Track Maintenance Methods on the Chicago Great Western R. R.
Abstract of an instruction pamphlet for foremen, outlining standard practice in conduct of routine track work. 5500 w.
Engineering Record, Vol. 64, p. 592; November 18, 1911.

Proper Lengths of Supervisors' Territory. Editorial.
A discussion of the mileage which should be assigned to supervisors and the common tendency to give them too large a territory. 700 w.
Railway Age Gazette, December 15, 1911, p. 1219.

A Combined Maintenance Organization. Editorial.
A discussion of the combination of track and signal forces on the Union Pacific. 800 w.
Railway Age Gazette, February 16, 1912, p. 290.

Evolution in Track and Signal Maintenance on the Union Pacific.
A. M. Foote.
A detailed account of the savings effected through the combination of these two maintenance forces. 3500 w.
Railway Age Gazette, March 15, 1912, p. 487.

Plan of Organization for a Railway Track Labor Department.
Wm. S. Wollner.
A description of a proposed plan for a company operated track labor department. 2200 w.
Railway Age Gazette, March 15, 1912, p. 495.

The Organization of the Extra Gang.
Eight discussions of the organization of floating or extra gangs for various classes of work. 6000 w.
Railway Age Gazette, May 17, 1912, p. 1101.
An editorial discussion of this subject appears on the preceding page. 1000 w.

Efficient Operation of an Extra Gang. P. H. Hamilton.
Railway Age Gazette, June 21, 1912, p. 1571. 1000 w.

Contracting Maintenance of Way Work on Railroads. Editorial.
A discussion favoring the contracting of Maintenance of Way Work. 300 w.
Engineering Record, Vol. 66, p. 283; September 14, 1912.

The Consolidation of Maintenance Forces. G. H. Bremner.
Advocates combining the track, bridge, building and other maintenance forces for the simpler problems. 2500 w.
Railway Age Gazette, September 20, 1912, p. 525.

How to Secure Foremen—Organization and Length of Section.
Abstract of committee report to Roadmasters' Association. 700 w.
Railway Age Gazette, September 20, 1912, p. 539.
Maintenance of Automatic Signals by Track Foremen.
Gives experience of Illinois Central Railroad.
Railway and Engineering Review, Vol. 52, p. 952; October 19, 1912.
Contracting Maintenance of Way Work. J. B. Cameron.
Favors contract for maintenance of way work and a number of small contractors rather than one large contractor. 400 w.
Engineering Record, Vol. 66, p. 475; October 26, 1912.
Labor Standards for Railway Maintenance Work. Editorial.
Advocates determining a standard day's work and measuring the efficiency of gangs accordingly.
Engineering Record, Vol. 66, p. 622; December 7, 1912.
Methods of Promoting Efficiency in Maintenance on the Pittsburgh & Lake Erie.
Evaluation of section work on a unit basis and the record system for keeping labor and material charges on all operations.
Engineering Record, Vol. 66, p. 624; December 7, 1912.
A Combined Maintenance Organization. A. M. Van Auken.
A discussion of the benefits which would follow the combination of track and bridge forces. 1000 w.
Railway Age Gazette, December 20, 1912, p. 1195.
A Suggested Organization for Combined Forces. F. W. Riser.
An organization is outlined for a consolidation of local division maintenance forces. 1200 w.
Railway Age Gazette, February 21, 1913, p. 339.
Organization of a Floating Gang to Train Foremen. W. H. Cleveland.
Advocates the maintenance of a gang whose primary purpose would be the training of men for positions as track foremen. 700 w.
Railway Age Gazette, March 14, 1913, p. 507.
Standard Track Work System. Earl Stimson.
An account of a system applied on the Philadelphia Division of the B. & O. R. R., which has resulted in increased efficiency. 1500 w.
Engineering Record, Vol. 67, p. 287; March 15, 1913.
The Efficiency of Maintneance of Way Labor. H. C. Landon.
A discussion of the character of labor employed, the organization of the gang and the methods by which the efficiency may be increased. 3000 w.
Railway Age Gazette, May 16, 1913, p. 1087.
Combined Organization of Maintenance of Way Forces.
Committee report of Roadmasters' and Maintenance of Way Association.
Advises against increasing the duties of section men. 800 w.
Railway and Engineering Review, Vol. 53, p. 862; September 13, 1913.
A Combined Organization of Maintenance Forces.
An abstract of a committee report to the Roadmasters' Convention. 800 w.
Railway Age Gazette, September 19, 1913, p. 517.
Combination of Maintenance Forces.
Committee report of Railway Signal Association. Finds the combination of maintenance forces a local problem. 1000 w.
Railway Review, Vol. 54, p. 513; March 28, 1914.
Some Ideas in Track Maintenance. F. H. Buffmire.
Discusses the importance of the labor problem, method of relaying rail, and other questions. 1500 w.
Railway Review, Vol. 54, p. 711; May 9, 1914.

Extending the Duties of Section Foremen.
Abstracted from a report of the Track Committee of the American Railway Engineering Association, describing various experiments in extending the jurisdiction of section foremen over other classes of work. 2000 w.
Railway Age Gazette, May 15, 1914, p. 1093.
Extra Gang Versus the Regular Section Gang. W. J. Potter.
Railway Age Gazette, July 17, 1914, p. 132.
Cost of Surfacing Track and the Features Which Influence that Cost.
Discusses the value of organization and details of the work. 3500 w.
Engineering and Contracting, July 22, 1914.
Organization Methods for $10,000,000 Track Elevation Program.
Unusual scheme adopted by the Rock Island Railroad on the heavy construction work near Chicago. 1300 w.
Engineering Record, Vol. 70, p. 122; August 1, 1914.
Proper Organization and Economical Use of Labor.
Abstract of a Committee Report presented before the Roadmasters' Association. 1500 w.
Railway Age Gazette, September 18, 1914, p. 522.
A Suggested Organization for Track Maintenance. G. O. Crites.
A detailed discussion of the reorganization of sections to increase their mileage and the size of the gang. 1000 w.
Railway Age Gazette, December 18, 1914, p. 1148.
Science of Organization.
Report to the Board of Direction of American Railway Engineering Association by Committee on Rules and Organization, 1915.
Proceedings, Vol. 16, p. 70.
Development of Pennsylvania R. R. Track Section System.
Jos. T. Richards.
A detailed description of the growth of the elaborate track inspection system in use on the Penna. R. R. and the results which are secured. 4200 w.
Railway Age Gazette, January 22, 1915, p. 153.
Organization for Track Maintenance.
Committee report of Roadmasters' and Maintenance of Way Association. Proposed plan of organization for track maintenance forces for the length of roadmasters' districts, track sections, etc. 4500 w.
Railway Review, Vol. 56, p. 221; February 13, 1915.
A Permanent Track Maintenance Force on the Long Island R. R.
Excellent results in keeping men by organization of permanent forces. 1000 w.
Engineering News, Vol. 73, p. 474; March 11, 1915.
Increasing the Scope of the Section Foreman's Duties. E. R. Lewis.
A discussion pointing out the objections to turning over to the track forces of additional work now commonly handled by other branches of the Maintenance Department. 1500 w.
Railway Age Gazette, March 12, 1915, p. 463.
Difficulties in Increasing the Scope of the Section Foreman's Duties.
J. P. Costello.
The disadvantages of combining other branches of maintenance work with that of the Track Department. 1800 w.
Railway Age Gazette, June 18, 1915, p. 1449.
Track Force for Renewing Rails.
Engineering News, Vol. 74, p. 752; October 14, 1915.
How Australia Builds Its Railroads. Morris E. Kernot.
Paper before the International Engineering Congress. Tells why direct labor has supplanted contractor on government owned lines. 3500 w.

Engineering Record, Vol. 72, p. 694; December 4, 1915.

Contract Fallacies from Australia. Editorial.
Discusses methods used by the Australian Government in dealing with Railroad Contractors. 500 w.
Engineering Record, Vol. 72, p. 682, December 4, 1915.

Efficiency in the Bridge and Building Department. Geo. W. Rear.
A discussion of the principles underlying the organization of bridge and building gangs and the treatment of men to secure satisfactory results. 3500 w.
Railway Age Gazette, December 17, 1915, p. 1160.

A System of Standardizing Maintenance of Way Work. Earl Stimson.
A description of the track efficiency plan of organization of track work, with detailed information concerning its application. 4000 w.
Railway Age Gazette, January 21, 1916, p. 111.

The Permanent Track Organization on the Long Island. G. P. Williams.
A description of the system by which track laborers are employed throughout the year. 2000 w.
Railway Age Gazette, January 21, 1916, p. 120.

Brazilian Opportunities and a Brazilian Railway. F. E. Lawrence.
Describes the organization and construction of the Brazil Railway and describes labor conditions. 500 w.
Engineering News, Vol. 75, p. 345; February 24, 1916.

Adequate Supervision. Editorial.
A discussion of the importance of providing sufficient supervision in the Maintenance of Way Department. 400 w.
Railway Maintenance Engineer, August, 1916, p. 226.

What Does Night Work Cost Compared with Day. Editorial.
Engineering News, Vol. 76, p. 323; August 17, 1916.

Studying Our Labor. Editorial.
A discussion of the importance of studying the characteristics of each nationality of track labor employed and the arranging of the work and organization of the gang to utilize these characteristics to the best advantage. 300 w.
Railway Maintenance Engineer, September, 1916, p. 257.

The Intelligent Use of Track Labor. W. E. Schott.
A discussion of the importance of utilizing different nationalities employed in track labor in those classes of work for which they are particularly adapted. 600 w.
Railway Maintenance Engineer, September, 1916, p. 260.

Cost of Night and Day Work. H. B. Whitney.
Engineering News, Vol. 76, p. 506; September 14, 1916.

Handling of Filipino Labor One of the Problems in Construction of Baguio R. R. W. M. Butts.
Description of labor and engineering problems encountered in the construction of a railroad to Baguio, Philippine Islands.
Engineering Record, Vol. 74, p. 351; September 16, 1916.

Cost of Night and Day Work. A. M. Shaw.
Engineering News, Vol. 76, p. 606; September 28, 1916.

The Seasonable Distribution of Forces.
Abstract of a committee report to the Roadmasters' Association, pointing out the opportunity for the extension of the working season in many classes of track work. 3500 w.
Railway Maintenance Engineer, October, 1916, p. 312.

Cost of Night and Day Work. Hunter McDonald.
Engineering News, Vol. 76, p. 798; October 26, 1916. 300 w.

Men Cheaper Than Machines on Trunk Line Railway Construction in China. E. Park.
Engineering Record, Vol. 74, p. 525; October 28, 1916.

Elements of Gang Organization. K. L. Van Auken.
Describes the importance of studying each individual problem and of distributing the forces to secure the best results. 1000 w.
Railway Maintenance Engineer, November, 1916, p. 344.

Experience of 41 Railways on Small Concrete Jobs.
Engineering News, Vol. 76, p. 849; November 2, 1916. 900 w.

Station Men System Succeeds on the Alaskan Railway.
Engineering News, Vol. 76, p. 995; November 23, 1916. 600 w.

Ballasting by Contract. John Evans.
Experience and cost data on Michigan Central R. R.
Proceedings American Railway Engineering Association, Vol. 17, p. 354, 1916.

Ballasting by Contract.
Report of Committee on Ballast, American Railway Engineering Association, 1916.
Proceedings, Vol. 17, p. 345.

Efficiency Methods on New York Central of Raising Track on Stone Ballast—Diagram.
Committee on Ballast American Railway Engineering Association, 1917.
Proceedings, Vol. 13, p. 464.

Conserving Labor. Editorial.
A discussion of the necessity of extending the working season over as many months as possible in order to complete the necessary work with the forces available. 700 w.
Railway Maintenance Engineer, March, 1917, p. 68.

Engineering Methods Must Replace Paternalism in the Handling of Labor. Frances A. Kellor.
Scientific planning should be applied to industrial railway management and embrace whole field of employment, promotion and housing. 3500 w.
Engineering News-Record, Vol. 78, p. 82; April 12, 1917.

Holding Men on the Job. Editorial.
Experience of the Rock Island Railway Company on track elevation work in Chicago. 800 w.
Engineering News-Record, Vol. 78, p. 216; April 26, 1917.

More Supervision Needed. Editorial.
Discusses the necessity of increasing the supervision in Maintenance of Way Department. 600 w.
Railway Maintenance Engineer, May, 1917, p. 138.

Labor Conditions and How Contractors See Them.
Shortage of supply and shifting of men from place to place constitutes a difficult problem and chief cause of decreasing efficiency. 8000 w.
Engineering News-Record, Vol. 78, p. 651; June 28, 1917.

Education, Training and Development of Laborers.

Railway Education in Europe.
Railway Age, Vol. 37, p. 297; February 26, 1904.

Why Efficient Track Work Is Skilled Labor. W. M. Camp.
The advantage of skilled labor in Maintenance of Way work. 2000 w.
Railway and Engineering Review, Vol. 47, p. 992; November 16, 1907.

Education and Organization of Railway Engineering Labor. J. E. Muhlfeld.
Advocates education of railway engineering labor. 3000 w.
Railway Engineering Review. Vol. 49, p. 77; January 23, 1909.

Educational Work in the Track Department of the Union Pacific.
A description of the work of the Educational Bureau of Informa-

tion in providing courses of instruction in the Maintenance of Way Department. 2200 w.
Railway Age Gazette, June 16, 1911, p. 1425.

Summer School in Track Work.
A description of the co-operative arrangement between the Union Pacific and the University of Cincinnati for the employment of students of the latter school in track work during the summer. 500 w.
Railway Age Gazette, June 16, 1911, p. 1430.

Classifying Track Work Between Skilled and Unskilled Labor. Editorial.
Discusses the possibilities of giving special training to certain groups of men to prepare them for foremen's positions. 400 w.
Railway Age Gazette, July 21, 1911, p. 124.

Educational Work in Track Department. Union Pacific R. R. 1800 w.
Railway Age Gazette, August 18, 1911.

Section Foremen Meetings. Editorial.
Discusses the benefits to be gained by holding frequent meetings of the section foremen. 700 w.
Railway Age Gazette, October 20, 1911, p. 780.

Track Apprentices. J. T. Bowser.
Advocates the employment of track apprentices to provide material for section foremen. 900 w.
Railway Age Gazette, May 17, 1912, p. 1117.

Training the Future Foreman. J. F. McNally.
A discussion of the most practical means for training these men. 1200 w.
Railway Age Gazette, May 17, 1912, p. 1119.

Studying the Section Foreman. E. R. Lewis.
A discussion of the responsibilities of this employe and the attention which should be given to his training. 2000 w.
Railway Age Gazette, August 16, 1912, p. 312.

The Track Labor Problem. Editorial.
Advocates improving track labor by education and training. 600 w.
Railway and Engineering Review, Vol. 52, p. 877; September 21, 1912.

Organization of a Floating Gang to Train Foremen. W. H. Cleveland.
Advocates the maintenance of a gang whose primary purpose would be the training of men for positions as track foremen. 700 w.
Railway Age Gazette, March 14, 1913, p. 507.

The Foreman Problem. A. Swartz.
Discusses several methods of training men for this position. 700 w.
Railway Age Gazette, April 18, 1913, p. 892.

Systematic Training of Foremen.
Discusses the need for a definite method for preparing men for this position.
Railway Age Gazette, May 16, 1913, p. 1078.

Making Section Foremen from Clerks. Wm. F. Wollner.
An outline of the plan for the traning of general office employes for positions in the Track Department. 2600 w.
Railway Age Gazette, December 19, 1913, p. 1187.

Development of Young Men in Railroad Work. Geo. M. Basford.
Paper read before the New England Railroad Club.
Railway Age Gazette, Vol. 56, No. 3; January 16, 1914.

Instructing Foremen in the Handling of Labor. Editorial.
Discusses the necessity of training men in the handling of other men. 300 w.
Railway Age Gazette, July 17, 1914, p. 113.

A Systematic Training of Supervisors. Editorial.
Discusses the elaborate method of training supervisors in force on the

Penna. and the results secured. 500 w.
Railway Age Gazette, July 17, 1914, p. 114.

Means of Increasing the Efficiency of Track Foremen in Handling Labor. W. E. Schott.
Some of the difficulties commonly encountered by foremen in getting the proper amount of work out of their men. 1000 w.
Railway Age Gazette, July 17, 1914, p. 120.

Two Methods of Training Section Foremen.
Description of two methods adopted by an eastern road to train men for the position of track foreman through the use of schools and positions as assistant foreman. 700 w.
Railway Age Gazette, July 17, 1914, p. 136.

Educational Work Among Employes in the Maintenance of Way Department. J. T. Bowser.
Suggestions for the placing of information in the hands of maintenance employes through technical magazines, etc. 1000 w.
Railway Age Gazette, November 20, 1914, p. 977.

Development and Promoting Men. Forrest Crissey.
Saturday Evening Post, Vol. 187, p. 9-11; April 17, 1915.

The Italian-English Course of the Pennsylvania Railroad.
A description of the educational course in track work which the Pennsylvania Railroad has provided for its Italian laborers. 1400 w.
Railway Age Gazette, August 20, 1915, p. 354.

Developing Track Foremen. K. L. Van Auken.
First of a series of articles. Discusses the labor problem. 2500 w.
Railway Review, Vol. 57, p. 796; December 18, 1915.

Developing Track Foremen. K. L. Van Auken.
Discusses methods of holding labor by good housing, feeding, good treatment, etc. 3000 w.
Railway Review, Vol. 58, p. 133; January 22, 1916.

Railway Education in Japan.
Railway News, Vol. 105, p. 435; March 11, 1916.

Fitting Men Instead of Firing Them.
Literary Digest, Vol. 52, p. 899; April 1, 1916.

Training Foremen. J. T. Bowser.
A discussion of the importance of division engineers and supervisors, giving adequate attention to the instruction of foremen regarding their duties. 700 w.
Railway Maintenance Engineer, November, 1916, p. 330.

Schools for Track Laborers' Children.
Describes a school maintained by the Southern Pacific for the instruction of the children of Mexican track employes. 800 w.
Railway Maintenance Engineer, November 1916, p. 337.

Training Young Men for Promotion. F. W. Thomas.
A detailed discussion of the importance of an apprentice system for the preparation of young men for positions in the Maintenance of Way Department, with a description of the plan in force on the Atchison, Topeka & Santa Fe for the preparation of employes in the Mechanical Department for positions as foreman. 3500 w.
Railway Maintenance Engineer, December, 1916, p. 377.

Improving the Foreman's Position. H. G. Clark.
A discussion of some of the measures which are being adopted to elevate the position of section foreman and to attract a higher grade of men into that work.
Railway Maintenance Engineer, January, 1917, p. 3.

Consider the Men We Have.
Discusses the necessity of improving the conditions of foremen already in the service and training them to become more efficient. 500 w.
Railway Maintenance Engineer, February, 1917, p. 35.

Training Maintenance of Way Men. F. W. Thomas.
A detailed plan for training track employes for the position of foreman and the discussion of the improvement in working conditions which will be necessary. 4000 w.
Railway Maintenance Engineer, April, 1917, p. 117.

Moving Pictures in Maintenance Work.
A description of the application of moving pictures to the instructions of track laborers on the Pennsylvania. 1500 w.
Railway Maintenance Engineer, April, 1917, p. 126.

Uplifting the Laborer.
Railway Review, Vol. 61, p. 263, September 1, 1917.

Appendix B.

(2) METHODS OF SECURING LABOR.

SUB-COMMITTEE.

R. H. Ford, *Chairman;*	W. R. Dawson,
R. A. Baldwin,	W. R. Hillary,
J. Q. Barlow,	C. B. Hoyt,
W. M. Camp.	

The following are the principal methods employed on American Railways for obtaining maintenance of way and construction labor:

(1) Through the Foremen:

This is generally applicable in rural districts.

(2) Through Padrones or Interpreters:

This is the method generally used in obtaining foreign labor. The laborers are engaged through their representative who, as a rule, either acts as an assistant or intermediary between the foreman and the men and is paid at the rate of an assistant foreman.

(3) Through Labor Agents:

These agencies are generally located in the larger cities where surplus labor congregates, the labor agent acting as a sort of middleman between the laborers and the railway. In many cases the railways undertake to obtain all their supply from some representative labor agent. The latter also may represent several railways.

(4) Through Contract Feeding Companies:

These companies contract with the railways to feed their labor and, in order to keep the camps full, they will also arrange with the railways to supply the laborers. As a rule, the latter are confined to the floating labor, but not to gangs of foreign labor. The feeding companies usually arrange with labor agents to supply the men for them.

(5) Through Exclusively Operated Railway Labor Agencies:

A few roads have provided their own labor agencies in about the same manner as that usually employed by the labor agent, but this has not been developed to any great extent.

(6) Through State and Federal Labor Bureaus:

This has been attempted to a greater or less extent of late years, but for various reasons it is seldom that these agencies can supply the class of labor that is required for railway purposes.

(7) Through Representatives of Foreign Governments:

In some of the larger cities these men have acted as labor agents for recent arrivals of immigrants from their respective countries in much the same manner as the independent labor agent does. Of late years, this has not been an appreciable factor and since the war it has ceased altogether.

The methods employed by the railways for obtaining labor have, in general, remained the same for many years. They have competed in the past with contractors and manufacturing establishments employing large numbers of common laborers. Labor agents or padrones were formerly the sources of the labor supply, but there has been a steady decline of late years in the classes of men that reach the labor agents. A large part of the better class of unskilled or common foreign labor that formerly went directly to the railways now reach the mills and factories through channels other than the labor agent, which results, as a rule, in a poorer class of labor only being left available for the railways through these agencies. There has also been a steady decline of all classes of common labor available for railway work, due to better and more remunerative opportunities in other lines of industry. The railways have met this condition in an unorganized and desultory fashion, adhering to original methods of employment and endeavoring to obtain the additional labor required by various practices such as maintaining a low hourly rate, but adding for extra hours not actually worked in order that the daily wage may be increased without affecting the hourly rate. Also a gradual lessening of supervisory effort on the part of the foreman and others in order to hold the men, has contributed to a greatly decreased efficiency. While these and similar methods are reprehensible and, as a rule, strongly condemned by the railways in general, it is unfortunately a fact that largely through a lack of appreciation of economic conditions these practices still continue.

The National Immigration law, which became effective May 1, 1917, requires a literacy test and, it is believed, will tend seriously to curtail the supply of common labor; but, with the exception of Mexico, its full effect may not be felt until after the war.

It is believed by the Committee that the time has come when there must be a better understanding by the railways of their labor problems; and more study given to the improvement in methods of securing, organizing and educating unskilled or common labor; also that there must be co-operation among the railways, looking towards the conservation of the labor supply, especially in the large centers.

Committees consisting of a representative from each railway entering the larger labor centers could, to advantage, be formed to study local labor conditions and to keep their respective companies informed of labor conditions generally. These local committees might be made up of persons who are directly concerned with the employment of the greatest number of laborers in the territory tributary to such centers.

In a study of cost for common labor by the Sub-Committee on labor of the Chicago Zone Railways (an organization consisting of all the roads centering in Chicago and supporting the Presidents' Conference Committee), the Sub-Committee has grouped and defined common or unskilled labor as follows:

(a) Native:

Consists of laborers who reside in the vicinity, most of whom maintain homes within access of the work. As a rule, this class of labor is the most efficient and no expense, other than the daily wage, is incurred by the employer. The amount of this class of labor available for construction work is usually insufficient.

(b) Foreign:

Consists of laborers who come to work in groups usually through a labor agent or one of their own number who acts as a leader. These men usually board themselves. Transportation and free housing are provided by contractors or the railway company.

(c) Hobo Labor:

Consists of tramp laborers, nearly all of whom are employed through labor agents; and for whom transportation, housing and feeding facilities are furnished by the contractor or railway company. Laborers in this group differ from those grouped as foreign laborers principally from the fact that they are employed singly and their continuity of service is of such short duration.

It is customary for railways to provide free transportation for common labor when entering their employ. Special equipment is sometimes necessary, and frequently these trips cover long distances. Foreign labor will generally arrive at the destination without desertion; but in the case of the hobo, there is considerable loss, the amount being proportional to the length of the trip and weather conditions. Cases are reported where special equipment was provided for shipments of over two hundred miles and less than 20 per cent. of the men arrived at destination. The average arrivals for all distances is probably about 85 per cent.

There is frequently a further loss of about 15 per cent. caused by the failure of laborers to accept actual service upon their arrival at the work. While this is especially true of the hobo, it applies, to a more or less extent, to all classes of laborers who come to the work singly. For extra gang and construction work it is customary, where possible, to ship men from the labor center so that they may arrive at the work in the morning or early part of the day in order that the men may be set to work immediately; otherwise, the loss from those not accepting service is increased. A certain percentage may be expected to desert after having obtained supper, lodging and breakfast without having performed any work whatever.

Foreign labor is affected quickly by rumors of slight increases in pay and better working conditions. It is not unusual for an entire force to leave the work on a few hours' notice. The rate of pay is not relatively so important with hobo labor as with other types of laborers.

Studies extending over some years indicate that free transportation and intoxicating liquors are among the important factors in promoting short service, which, in the case of hobo labor, is its greatest drawback. These conditions are aggravated by poor working conditions and surroundings. While longer service is obtained from foreign labor transported free of cost, the practice is open to more or less criticism. By means of this universal free movement, common labor is enabled, often upon a mere whim, to move back and forth without cost to the laborer from one part of the country to the other; causing a great decrease in man-power with resulting disorganization and increased cost of work to the railways. It is a question whether better results would not be obtained if all roads were to discontinue this practice and charge for transportation on some basis that, while protecting work at a distance from labor centers, would discourage this wandering tendency of much of the common labor.

Unfortunately, it does not rest with the railways to entirely remove this source of difficulty. A large percentage of free travel is on freight trains, between, in and under cars, which for various reasons, the railways have apparently been unable to control. Town and city ordinances contribute, to some extent, to this troublesome problem. Better co-operation between the railways and states would do much to improve this condition.

In its Chicago district, the Chicago, Rock Island & Pacific Railway Company has for several years maintained a record of the length of service, and reasons assigned by track and construction laborers for leaving its service. The following statement covering the years 1916-1917 is indicative of this:

ROCK ISLAND LINES

STATEMENT OF "HOBO" LABOR

By Months June 17, 1916, to December 16, 1916, and May 26, 1917, to October 20, 1917.

MONTHS	Number Employed	Number Time Checked	Average Days in Service	REASONS GIVEN FOR LEAVING														NATIONALITY									
				Sick	Need Money	Need Clothes	Poor Food	Poor Water	Too Hot	Too Cold	Dissatisfied	Work Too Hard	Better Job	Joined Army or Navy	Laid Off	Discharged	Miscellaneous	American	English or Scotch	Irish	Swede	German	Slav	French	Italian	African
1916																										
June........	114	44	4.5	4	9	6	7	.....	.....	.....	3	9	.....	.....	.....	.....	6	21	.....	11	1	6	5	....	....	....
July........	575	386	4.5	47	69	15	86	.....	52	.....	25	18	.....	.....	.....	2	72	97	.....	139	45	59	43	1	2	....
August......	590	371	3.5	66	52	12	40	23	57	.....	27	41	.....	.....	.....	2	51	89	.....	155	33	50	40	2	2	....
September...	527	251	5.9	59	33	11	8	.....	2	.....	37	16	11	.....	.....	.....	74	68	.....	87	30	32	33	....	1	....
October.....	395	180	4.9	32	22	33	16	.....	.....	.....	7	6	10	.....	.....	3	51	43	.....	78	16	29	11	1	2	....
November...	415	183	5.1	30	21	28	2	.....	1	14	17	6	.....	.....	.....	4	60	44	.....	60	25	26	26	....	2	....
December...	258	131	5.4	12	8	12	5	.....	.....	16	2	1	17	.....	.....	.....	58	26	.....	43	26	22	14	....	....	....
Total.....	2874	1546	4.8	250	214	117	164	23	112	30	118	97	38	.....	.....	11	372	388	.....	573	176	224	172	4	9	....
1917																										
May........	40	4	1.5	.....	2	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	1	1	.....	.....	.....	1	....	1	....
June........	435	190	12.6	22	32	7	9	.....	6	.....	21	3	28	4	27	8	23	36	3	73	9	7	2	2	17	41
July........	391	169	11.5	15	22	8	7	.....	10	.....	26	.....	10	2	21	.....	48	21	4	90	3	11	6	....	9	25
August......	308	110	20.4	25	13	1	8	.....	2	.....	20	1	18	2	10	1	9	36	2	48	2	7	8	....	4	3
September...	300	167	10.5	27	31	4	17	.....	.....	.....	34	3	16	3	8	4	20	45	3	64	7	10	16	1	5	16
October.....	275	146	9.2	31	42	8	5	.....	.....	8	14	1	9	.....	1	2	25	23	2	40	5	7	9	1	1	58
Total.....	1749	786	11.0	120	142	28	46	.....	18	8	115	10	81	11	67	15	125	162	15	315	26	42	42	4	37	143
Grand Total.	4623	2332	7.9	370	356	145	210	23	130	38	233	107	119	11	67	26	497	550	15	888	202	266	214	8	46	143
Per cent to "Number Time Checked".................				15.9	15.3	6.2	9.0	0.9	5.6	1.7	10.0	4.6	5.1	0.5	2.9	0.9	21.4	23.6	0.6	38.1	8.7	11.4	9.1	0.4	2.0	6.1

Unfortunately, the true reasons are not always given and the figures can only be taken as pointing to the probable cause; the desire for ready money is more frequently the reason. Laborers will leave and return to the same job in the course of a few days; the lost time being spent in idleness. Co-operation between railways and local authorities and better housing and working conditions would greatly ameliorate this condition.

It will be noted in the above statement that the average length of service for the year 1917 is materially increased over that of 1916. This is in part due to greatly improved boarding and housing facilities.

Data is not available to show the effect on common labor of the severe retrenchments by the railways during the past ten or fifteen years, but it is probable that it has increased the tendency for engaging relatively more men during the comparatively short working season with corresponding reductions in the unfavorable seasons, as well as increasing, somewhat, the tendency to more frequent increasing and decreasing of force rather than to transfer laborers from one point to another in order that they may remain in continuous service. In former years this was not as much of a problem, because railway construction and large miscellaneous improvement work in various parts of the country readily absorbed surplus railway labor and gave opportunity, for men familiar with such work, not only to continue in this line of employment, but to increase in skill and efficiency. The steady decline and ultimately the practical cessation of railway construction has closed this avenue of employment and much of the railway labor has been forced into other service. The gradual drifting into other lines of employment has had its effect on the supply of efficient railway labor, for there is a natural tendency for men to remain in these other classes of service, especially as the pay and living conditions are better, as a rule. Much of the better labor does not come back and this has greatly reacted against the efficiency and education of track labor and made the service less attractive.

The stopping of immigration caused by the war and the effects which must culminate because of it has, however, completely changed conditions. The conditions brought about by the war now make it imperative that readjustments be worked out which will have for their purpose better conservation of man-power, and more careful selection and continuity of service of the common labor necessary to maintain the railroads.

The Committee desires that this be considered a progress report, and that the subject be continued during the coming year.

Appendix C.

(3) FEEDING AND HOUSING MAINTENANCE OF WAY AND CONSTRUCTION EMPLOYES.

SUB-COMMITTEE.

E. T. Howson, *Chairman;*	C. M. James,
W. J. Backes,	J. C. Nelson,
A. F. Blaess.	C. A. Paquette.
R. H. Ford,	

In any study of the present acute shortage of labor in the Maintenance of Way Department and of the reasons for this condition, one is quickly brought to realize the fact that while the scarcity of men is intensified at the present time, there are certain basic conditions which cause the railways to suffer first and most acutely in each recurring period of industrial activity. In other words, the railways are not competing successfully with other industries for men, and when men have a choice of work they leave the roads for the contractor or the factory.

One of the most important if not the governing reason for the failure of the roads to retain adequate forces when men are scarce is the disparity in wages in comparison with competing industries. However, important as the wage is, it is not the only and frequently not the principal consideration. The conditions under which the men are required to work and to live are important in their estimation and rightly so. The importance of comfortable living quarters and an ample supply of good food, well cooked, as a means of holding men, has not been realized by railway companies as fully as by the contractors, and the failure on the part of the roads to provide these conditions has had no small part in bringing railway work into disfavor among the men and causing them to seek other sources of employment at the first opportunity.

Your Committee has been instructed to investigate and to report on Feeding and Housing Maintenance of Employés. Although this would include skilled labor, such as carpenters and plumbers as well as unskilled floating gang laborers, the Committee has limited the investigation at this time to the latter class of men who are employed in the track department, as it is among this class of men that the greatest shortage exists and the most acute problem is presented at the present time.

To ascertain the methods now being followed by the roads in feeding and housing those of their track laborers who are dependent on them for these accommodations, a circular letter was sent to the officer in charge of maintenance of way on 80 roads asking for the following information:

(1) Character of labor employed (native, colored, Italian, etc.).

(2) The extent to which it is necessary to provide housing and feeding accommodations.

(3) The character of housing provided (cars, camps, etc.).

(4) The character of equipment provided (bunks, bedding, etc.) and by whom furnished.

(5) The extent and nature of the sanitary regulations provided, giving some details, and the regulations enforced.

(6) Methods of feeding your men (by contract or company commissaries, by the men themselves, etc.).

(7) Methods of charging for board, including determination of rate.

(8) The relative advantages and disadvantages of these systems. (Questions 6 and 7.)

(9) What supervision do you exercise over the feeding and determination of rate.

(10) To what extent have you recently or are you now remodeling and improving your camp and boarding facilities.

(11) What effects have you noticed or do you believe result from good camps in the way of holding men? Information concerning definite instances particularly solicited.

Fifty replies to this letter were received which have been tabulated in Addenda (1) and are discussed below:

EFFECT OF CHARACTER OF LABOR ON ACCOMMODATIONS.

No one type of camps or method of feeding men can be offered as a standard applicable to all roads or even to all gangs on one road or on one division of a road. In many ways each camp is a problem in itself, although a successful plan at one point will be applicable to other camps of the same general character. In the report which follows, the Committee has not attempted to recommend any one plan or practice, but it has endeavored to point out the divergent methods used on different roads and in some cases to indicate the advantages and disadvantages, hoping that this review of these practices and the discussion which may follow in the convention will contain suggestions for adoption on the individual roads.

The most important condition governing the character of the housing and of the food provided is the nationality of the men in the gang. The Italian does not desire the same kind of food as the hobo nor does he want it provided in the same way. Almost every nationality and class of labor employed on track work has its peculiarities and customs which must be respected, if the men are to be retained in the service of the road.

In the South the negro is employed almost exclusively. For instance, 95 per cent. of the track laborers on the Seaboard Air Line are black, the remaining 5 per cent. being native white men. However, the negro track laborer is not confined by any means to the South, for the extensive migration of this race North during the last few years has brought them in large numbers into the states north of the Ohio River, into New England and onto lines in the Northwest, such as the Great Northern. This migration has been so heavy in some portions of the

South that it has been necessary to bring in other laborers to fill their places. For this reason Mexicans were employed in Mississippi and Alabama last summer, and the Southern Railway was one of the first roads to apply to the Government for some of the Porto Rican labor which the United States Department of Labor considered importing into this country last fall.

In New England and the states east of Pittsburgh and north of the Ohio River, track labor has been largely foreign in recent years, with Italians, Greeks and Austrians predominating. These men are readily attracted to other employment by relatively small increases in wages and with the widespread industrial activity in this area during the last three years, track forces have been seriously depleted. This has been overcome in a measure by the importation of negroes from the Southern States as referred to above. Some roads have also brought Mexicans from El Paso and other points on the border as far east as New York.

The greatest variety in the character of track labor is to be found on roads in the Middle West. The native white has been replaced in large measure by the hobo, the Italian and the Greek, although within the last six or eight years the Mexican has been brought North in large numbers, and the negro has also come in during the last two or three years. As a result representatives of nearly all nationalities are found in the track forces in this part of the country. This condition extends into many of the gangs themselves, one section gang of seven men on a western road being noted recently to consist of a Japanese foreman, one Japanese, one Mexican, two negroes and two Armenian laborers.

There is a greater uniformity in the character of the track labor employed on the roads in the Southwest than in any other part of the country at the present time, Mexicans being found almost exclusively. As more Mexicans have come into this country, their sphere of activity has extended northward as well as east, although the alien immigration law, which went into effect May 1, 1917, will largely arrest the influx and spread of this class of labor.

From the above it is evident that the highly localized labor of a few years ago has now become a thing of the past. The conditions of the last three years have caused almost all classes of men to move more freely from one part of the country to another than ever before, with the result that there is a greater diversity of forces on almost every road than was found a few years ago. This condition makes necessary the closer study of the housing and feeding of these men in order that their wants may be satisfied in a manner approximating that to which they have been accustomed, for unless this is done they will become dissatisfied and go to other work. On many roads the class of men now employed demand widely differing accommodations from those provided a few years ago.

Extent to which housing is necessary depends on a number of conditions other than the nationality of the men employed. Important among these are the availability of local accommodations and the extent to which the gangs are moved from place to place. The practice is quite general over the country to provide houses for section foremen at points where the foremen find difficulty in arranging for them. Although limited originally to such points where they were provided to enable the roads to hold foremen, this practice has spread on some roads until it has become standard to provide such houses. Thus it is the standard practice of the Louisville & Nashville and of the Seaboard Air Line to furnish each section foreman with a house. Where this is not done the latter road allows its foremen $8 per month additional wage in lieu of the house.

In past years it was unnecessary, except in isolated instances, to provide housing for section forces, as they were recruited locally and lived at home. With the advent of the foreigner into track work it has been necessary to provide lodging for him as he is unable to secure accommodations in many communities along the line. This has led to the very common provision of bunk houses at section headquarters in which these men can live. Such facilities are provided for about 75 per cent. of the track forces on the Long Island, which employs foreign labor almost exclusively.

The character of the housing provided for section laborers varies widely. On the Seaboard Air Line, where the negro is employed almost exclusively, it is the standard practice to provide four houses for the use of that number of laborers and their families at section headquarters in addition to the house for the foreman, enabling each negro laborer to bring his family with him. On those roads in the Middle West on which both native and foreign laborers are employed in section gangs, housing is commonly provided only for the foreigner, although no difference is made in the wage.

Car bodies removed from the trucks and placed on the ground are most commonly provided as living quarters for these men, although a number of roads have designed and built bunk houses for this purpose. Where it is necessary to provide housing for laborers of this character, the latter practice is much to be preferred. The car body has little to recommend it other than its ready portability and its supposedly low first cost. At section headquarters, where accommodations of this character will be required permanently or for extended periods, a road can well afford to provide more convenient and sanitary arrangements.

The provision of housing accommodations is even more necessary with extra gangs. Even if the work is such that a gang may be located at one point for a considerable period, it is frequently impossible to recruit a sufficient force locally; and it then becomes necessary in most instances to house such gangs in camps. Thus the New York, New Haven & Hartford operated 27 permanent camps last summer with a combined capacity of 1931 men.

In addition to these fixed camps it is necessary to house the men in floating gangs who move from one place to another as the work progresses. This is the more common condition, particularly on the railways in the West, where extra gang work is confined very largely to the renewal of rail and ballast and to similar work which progresses from one point to another.

The character of the camp provided at any point depends in large measure on the extent to which it is necessary for the gang to be moved from place to place. Where a force is to be located at one point for any considerable length of time, as at a gravel pit or on construction work, buildings of a semi-permanent character are provided. Where the number of men to be accommodated is larger than can be handled in one or two car bodies or small bunk houses, frame buildings are easily erected for this purpose. These buildings are of widely differing designs, depending upon local conditions and on the expenditure which a road is willing to make. When in incorporated cities, these standards are frequently established by the requirements of the municipalities, both as to forms of construction and sanitation.

More commonly it is necessary to move gangs from place to place at frequent intervals, making necessary the provision of portable camps of one kind or another. The earliest and the most common type of portable camp is the converted box car. In most cases the cars which are in this service are small and of light capacity, and for this reason they have frequently been condemned as unfit for revenue service. From the nature of its construction a car of this character is difficult to maintain in a sanitary manner and, as a result, it has come into quite general disfavor among laborers in recent years. Because of the important advantage of ready portability the railways have been hesitant about giving up cars for the housing of men, but the general prejudice against them because of their unsanitary condition has led a number of roads to revise their standard plans materially to improve conditions during the last three or four years.

One of the most important objections to the old type of car was the number of men crowded into it, bunks being ordinarily provided for 16 men in a 34-ft. car. Probably the most important improvement which a number of roads have made in the design of their cars has been to reduce the number of men housed in each car. An excellent feature of the bunk car of the Delaware, Lackawanna & Western is the positive limitation of 8 men to a car.

Another important consideration in the design of a bunk car is ventilation. Until recently it has been the common practice to place two windows in each end of a car, one on each side. A practice much to be preferred is that of the Missouri Pacific car, whereby a window is placed opposite each upper and lower berth.

One feature which deserves careful consideration in these days of heavy freight trains is the safety of the men as they are moved from place to place in the cars. Operating rules usually provide that such cars be placed at the rear end of trains to lessen the danger to occupants. However, at best these cars are in many cases old and of light construction. For this reason the Elgin, Joliet & Eastern and some other roads have equipped all bunk cars with steel underframes.

In many cases it is not possible to equip a sufficient number of cars from those condemned for revenue service and it then becomes necessary to take other cars from commercial traffic. The car shortage of this year has illustrated the cost of this practice and has given an incentive to the development of substitutes for the box car which still possess the advantage of portability. Thus the Chicago, Milwaukee & St. Paul has designed a sectional building about the size of a car body, which is built of new lumber by company carpenter forces and which can be taken down and loaded on a flat car for movement from place to place. The Chicago & Northwestern has developed a somewhat larger building which can be handled in the same way.

The Southern Railway and a number of other roads have equipped some of their gangs with portable steel buildings, several types of which are now on the market. An important advantage of these portable buildings is the readiness with which they may be fumigated and maintained in a sanitary condition.

Other roads have resorted to tents in which to house floating gangs. The Los Angeles & Salt Lake housed a number of gangs in tents equipped with board floors last year. The Buffalo, Rochester & Pittsburgh also used tents for two or three years, although it has recently abandoned them for portable shanties.

EQUIPMENT PROVIDED IN CAMPS.

The character of the equipment provided in bunk cars and the responsibility for its provision vary greatly on different roads and, in many cases, between different camps on the same road. It is the common practice for a railroad to provide the bunks in the cars and also stoves. Beyond this point the responsibility varies, the men providing their own bedding in some instances and the contractor doing this on other roads, while on still others all bedding equipment is provided directly by the railways.

Until a few years ago wooden bunks were almost universally employed in cars and in camps, these bunks frequently being installed in the cars by carpenters in the spring and removed at the close of the season when the cars were returned to revenue service. Aside from the expense of equipping the cars with wooden bunks, these bunks have been objectionable because of the great difficulty in keeping them free from vermin and dirt; and they have been unsatisfactory in other ways. This has resulted in a rapidly increasing use of metal bunks of which several types are now available. While wooden bunks are still to be found in many camps and on many roads, they cannot now be considered in accord with the best modern practice and are not to be recommended for a modern camp.

The men are required to provide their own bedding on a number of roads, including the Seaboard Air Line, the Louisville & Nashville, the

Great Northern, the Kanawha & Michigan and the Illinois Central. On other roads, including the Canadian Pacific, the Missouri, Kansas & Texas, the St. Louis-San Francisco and the St. Paul, bedding is furnished by the boarding contractor in connection with his arrangement for the feeding of the men. Other roads, particularly in the East, provide the bedding themselves. On the New Haven the superintendent of dining cars furnishes part-wool blankets and mattresses for the men in the camps. The Maine Central provides similar equipment. On the Pennsylvania Railroad and the Delaware, Lackawanna & Western, each man is provided with a mattress, two blankets, one pillow and a pillow case. The New York Central Lines have provided mattresses for camps for many years and have recently begun to provide blankets for part of the gangs. On the Southern each laborer is given a mattress, one blanket and a quilt on an order signed by the Supervisor or the General Foreman.

Other facilities commonly provided by the railways at camps include stoves, washbasins, etc. There is also a distinct tendency in the more modern camps to provide conveniences for the men, such as shower baths, hot and cold running water, sanitary toilets, etc. In addition to these facilities the Baltimore & Ohio has added a steaming room for the steaming of clothing, and stationary tubs for the washing of clothes in some of its more recent camps.

Another development in some of the more modern camps is the provision of a separate room or car for a lounging or clubroom in which the men can spend their spare time. In some instances where camps have been so equipped, daily and illustrated papers are provided and other inexpensive attractions offered to occupy the spare time of the men and keep them more contented in the service.

THE FEEDING OF EMPLOYES.

The best method of feeding track laborers is a much disputed question and one concerning which there is much controversy at the present time. Without doubt no one method is equally applicable to all nationalities and to the widely varying conditions. At the same time no one phase of the treatment of track labor is more open to criticism at the present time than this, and it is important that the railways give this subject more attention.

With some nationalities, as, for instance, the Italian, it is necessary to allow the men to feed themselves in their own way. While this frequently results in their underfeeding and lessens their efficiency, it appears to be the only arrangement under which the men will work, On the Baltimore & Ohio some gangs of this character buy their food locally and prepare it themselves, while at other points arrangements have been made whereby the men can buy it from a regularly established commissary company. However, in most cases it is not only possible for a road to feed its men directly, but it is actually necessary for it to do so, as the only practical way in which the men can be fed.

In the South it is the very general practice for a foreman to feed his men and to charge them for board, the company protecting the foreman against loss by deducting the amounts due him from the pay of the men. This is the practice on the Louisville & Nashville, the Kanawha & Michigan, the Richmond, Fredericksburg & Potomac, and the Illinois Central, although recently the latter road has contracted the feeding of some of its larger gangs and has provided company commissaries at other points. With this plan it is possible for the men to express their desires regarding the amount and character of their food directly to the foremen and to secure what they want more readily. The most serious objection to the plan is the difficulty in preventing some foremen from taking advantage of the men through excessive charges and in other ways. While most roads on which this system is in effect provide supervision of the charges for board made by the foremen, it is very difficult to detect and to prevent irregularities, particularly among colored laborers. As one check on the charge for board, the Illinois Central limited the deduction on this account to 50 per cent. of the amount due each man until last year when, because of the increased cost of food, this limit was raised to 65 per cent. On the New York Central Lines west of Buffalo it was formerly the universal practice for the foreman of each gang to buy the provisions and collect from the men pro rata for the exact cost of the food, and this practice is still followed with white men. Foreign laborers are now fed by the Track Supervisor through the foremen at a fixed rate per man which allows the Supervisor no profit, while negro gangs are boarded at a fixed price per week, the charge being deducted by the company in all cases.

Where the men are fed by the foremen the collection of the amounts due for board are left entirely to the foremen on the Grank Trunk and the Kanawha & Michigan. In general, however, the company deducts from the pay the amount due to cover this charge. On the New York Central Lines west of Buffalo each man in the signal gangs is required to deposit with his foreman a sum equal to the estimated cost of his board for the week, each Monday morning, while men in the bridge gangs pay their pro rata charge of the cost of their board at the end of each week.

The practice most commonly followed in the West is to contract the boarding of all gangs to a contractor specializing in this work and to leave all details regarding the purchase and preparation of the food to him, the company deducting the amount for board from the pay of each man and turning it over to the contractor directly. With such an arrangement the railway usually provides the cars or camps and supplies such as stoves and tables, while the contractor furnishes the dishes and cooking utensils and all kitchen help. Generally the contractor who feeds the men in the camps also operates a labor agency with a view to keeping the gangs full. By this method a railway transfers the responsibility for the feeding of its men to an organization specializing in this work and gains the benefit of this specialization. At the same time this arrangement introduces a third party between a railway and its employes whose interests generally do not coincide with those of either of the other two.

This conflict of interest has led to the operation of commissaries and the feeding of men directly by the railways in a number of cases. The New York, New Haven & Hartford, the Delaware, Lackawanna & Western and the Pennsylvania Railroad have adopted this plan, and the latter road reports that camps operated in this manner are much preferred by the men. In general the policy of a road furnishing its own camps is to provide the men with a sufficient amount of proper food and without profit, removing the tendency for the exploitation of the foremen.

Where the boarding of the men is contracted to a commissary company the rate per meal, or more commonly per week, at which the men are to be charged is determined by agreement between the company and the contractor, and the men are advised of this arrangement when hired. The amount due the contractor is then deducted by the company from the wages due each man and is remitted directly to the contractor.

On the Nashville, Chattanooga & St. Louis the company boards its own men in every gang except one or two special organizations employed on construction work. The men are charged for board on the basis of the cost which was computed several years ago, this amount being deducted from the daily wage. No deduction is made for rainy days, while gangs are moving, or where men fail to work for any other reason. No readjustment of this charge has been made in recent years on account of the increased cost of supplies.

To compensate a boarding contractor for the increased cost of foodstuffs and at the same time to keep the rates charged the men for board at a reasonably low figure, the Buffalo, Rochester & Pittsburgh now pays the contractor five cents for each meal furnished a laborer actually at work. The Maine Central accomplishes the same purpose by reimbursing its foremen, who feed their men, for the actual cost of board in excess of 50 cents per day. The New Haven pays part of the cost of board in still another way, charging the men $4 per week for the first four weeks they are in the service of the company and $3.50 per week thereafter. This latter rate, which is less than the actual cost to the company, is offered as an inducement to the men to remain in the service. The Southern goes still further with its extra and construction gangs, paying them a fixed wage in addition to board and then paying the contractor for all meals served without making any deductions from the pay of the men. This eliminates all accounting between the company and the men and removes all uncertainty and cause for dispute concerning deductions from the pay checks, a very important consideration in the mind of the negro.

Another method to protect a boarding contractor against the high cost of foodstuffs is to pay him the actual cost of the food and service plus a fixed percentage. This plan was adopted at several camps on the Big Four last year and has also been tried on other roads.

The amount of supervision given the character of the food served to the men, or the manner of presenting it, varies to a considerable extent according to the system under which the men are being fed. Where they feed themselves directly or through arrangements with their foremen, little attention is ordinarily paid to the subject except to see that the charges are not exorbitant. Where the feeding is done by a contractor, closer inspection is required, although a number of roads have reported that no attention is given to this subject even under this arrangement except when complaints are received. In general, however, the local Superintendent, the Division Engineer, the Supervisor and the foremen are expected to inform themselves regarding the service given the men and to see that the contractor fulfills his contract. A number of roads expect their Roadmasters to eat at these camps at frequent intervals in order to inform themselves regarding the character of the food served.

SANITARY PRECAUTIONS.

One of the most commonly neglected details about a camp and at the same time one of the most important both for the health of the men and for their efficiency on the work, is that of camp sanitation. In reply to the inquiry of the Committee a number of roads stated frankly that they were doing nothing along this line. This situation is only too common and has given rise to regulations by state and local boards of health which are frequently unnecessarily drastic. From the standpoint of the efficiency of its workmen alone, a company is justified in requiring that ordinary sanitary provisions are enforced, while from the standpoint of its duty as a property owner in the community through which it passes, a railway should not wait until it is forced to remedy unsanitary conditions.

In some instances, on roads which are giving attention to this subject, the sanitation of maintenance of way camps is under the direction of a company medical officer who issues instructions and then sees that they are enforced. More frequently this supervision is left to the local Roadmasters and foremen. Where camps are operated by boarding contractors, a clause is frequently inserted in their contracts to the effect that proper sanitary measures are to be observed about the camps; but this requirement is frequently not enforced. In any case, frequent inspections by the local officers are absolutely necessary. On the Chicago Terminal of the Chicago, Rock Island & Pacific, this inspection is made by the local company physicians, who are required to inspect all camps and bunk houses thoroughly each month and to recommend any needed improvements.

The first and most important detail requiring attention is that of toilets. Suitable facilities should be provided at every camp, and the men should be required to use them in so far as practicable. Ordinary dry closets are most common, in which case they should be moved at frequent intervals and the pits covered or lime applied.

Another problem which requires attention is the prompt disposal of garbage. On the New York Central Lines a trench is dug along the right-of-way fence and the garbage is buried under it. On the Norfolk & Western, barrels are provided for the refuse, which is dumped at isolated points daily. On the Missouri, Kansas & Texas and the Duluth, South Shore & Atlantic, all such refuse is burned.

A very important precaution is the provision of an ample supply of pure drinking water. On the Chicago & Northwestern water cars are attached to each camp outfit which is located at a point where the local water has not been approved by the medical officer and water is hauled to the camp from some source of approved quality. These water cars are sterilized with live steam at frequent and regular intervals.

The frequent fumigation of camps is another important provision to keep them sanitary and free from vermin. The Illinois Central requires that all bedding be taken out of the buildings and cars and aired at least twice each week, and the Supervisors are required to make inspections to satisfy themselves that this is done and that the cars are kept clean. On the Southern all cars, houses, bedding and fixtures are sprayed with a disinfectant as often as necessary. On the Great Northern the maximum interval between applications is placed at three months. Sulphur is employed to fumigate camps at regular intervals on the New Haven. On the Delaware, Lackawanna & Western the camp cook and his assistants are held responsible for the maintenance of the camps in proper condition. Bunk cars are required to be washed and all bedding hung outside in the air daily. All sheets are laundered once each week. All camps on this line are also fumigated thoroughly every three months.

RECENT IMPROVEMENTS IN CAMPS.

The increased attention which is now being given to camps is bringing a greater realization of the unsatisfactory conditions which have been allowed to develop. This is leading to improvements in the provisions for the housing of laborers by many roads. Some of these are indicated in the replies which the Committee received to its letter of inquiry, and are abstracted below.

Earl Stimson, Engineer Maintenance of Way, Baltimore & Ohio:

Stationary camps are being erected wherever possible. These are equipped with steel bunks, bath facilities, sanitary kitchens and toilets, completely screened and ventilated. Large airy bunk houses are replacing camp cars and bachelor camps are being replaced with commissary boarding camps.

E. G. Lane, Engineer Maintenance of Way, Baltimore & Ohio Southwestern:

We are improving our camp and boarding facilities constantly by repainting, whitewashing, disinfecting and wherever possible, providing shower baths.

F. B. Freeman, Chief Engineer, Boston & Albany:

We are improving all the time, furnishing old coaches instead of box cars, steel bunks instead of wood; insisting on greater cleanliness.

B. M. Cheney, General Inspector Permanent Way and Structures, Chicago, Burlington & Quincy:

We are gradually replacing wooden bunks with steel bunks, screening all cars and providing additional windows.

W. H. Penfield, Assistant to Vice-President, Chicago, Milwaukee & St. Paul:

Much more attention is being given to the housing and feeding of laborers than was customary in the past. Every effort is being made to provide clean and attractive living accommodations, satisfactory meals and lodgings. Bunk cars and houses are provided with a much better class of beds than formerly; screens are provided for the cars and every effort is made to keep them clean and sanitary. This is absolutely necessary, as the men will not remain long in a camp which is not entirely satisfactory to them.

E. R. Lewis, Assistant to General Manager, Duluth, South Shore & Atlantic:

We have recently installed a system of paying the contractor's cooks and keeping the contractor's books with a view to protecting the company financially and with a view to keeping down the cost of board, rather than increasing the wages of laborers.

G. B. Owen, Superintendent of Maintenance, Erie:

We have recently constructed about twenty camps and ten barracks with improved ventilation and sanitary conditions and are remodeling old bunk cars in conformity therewith.

J. R. W. Davis, Engineer Maintenance of Way, Great Northern:

We are gradually improving the bunks to the extent of using steel bunks and springs and also more windows and space in cars.

A. F. Blaess, Engineer Maintenance of Way, Illinois Central:

We have done much in the past year toward improving our camp cars and temporary bunks. The cars have not all been overhauled, but they are being overhauled as rapidly as we can get them in the shops, being screened and fixed up so they can be kept more sanitary, equipped with steel bunks and, generally speaking, made more comfortable than has been the practice heretofore, in order to keep the men more satisfied and contented. The commissary we have recently built on our Chicago Terminal near Wildwood consists of several sets of buildings, one of them to take care of the construction work and the other maintenance work on the terminal property. Each one of these units contemplates taking care of from 100 to 125 men, and consists of four or five buildings, sleeping 24 men each:

One building, equipped with running water, shower baths, lavatories and toilets.

One building for commissary, kitchen and dining room.

One small building for use in case the men become sick.

These buildings are equipped with electric lights and sanitary steel bunks.

C. M. McVay, Engineer Maintenance of Way, Kanawha & Michigan:

All new camp cars being built are provided with steel bunks. We are also reducing the number of bunks per car where possible.

F. Ringer, Chief Engineer, Missouri, Kansas & Texas:

Realizing the importance of providing adequate and sanitary outfits, it is our purpose to replace all wood bunks with metal bunks as fast as practical; also to provide satisfactory facilities for housing laborers on sections.

E. A. Hadley, Chief Engineer, Missouri Pacific:

Particular care is exercised in keeping the outfit cars clean and supplied with all conveniences consistent with the character of work. Any suggested improvement is promptly put into effect for test, and, if found desirable, adopted as standard.

H. B. Reinsagen, Engineer Maintenance of Way, New York Central Lines:

We are improving our camp cars steadily and rapidly. We are using more coaches, preventing men from tearing their cars in pieces, and painting the cars for sanitary purposes. We are putting up better houses with water pressure and better sanitation.

W. J. Backes, Engineer Maintenance of Way, New York, New Haven & Hartford:

Stationary or permanent camps have been erected at South Norwalk, Rowayton, Montewese, Derby Junction, Waterbury and Midway, Conn., Uxbridge, Mass., and other points, and camps are now being constructed at Holbrook and Islington, Mass., the last-mentioned with a capacity for 130 shop and roadway men, being probably the most complete. Camps are equipped with cement floors and can be washed out and kept in sanitary condition. Upon receipt of material, they will be provided with toilets, shower baths, basins, etc.

Job Tuthill, Chief Engineer, Pere Marquette:

Cars are kept in good condition as it is possible to equip that kind of equipment.

B. Herman, Chief Engineer Maintenance of Way and Structures, Southern:

We are now preparing standard plans for remodeling and improving our camp cars.

IMPORTANCE OF GOOD CAMPS.

The effect of good camps and boarding facilities on men is indicated by the following comments which were received in reply to the circular letter of the committee:

F. B. Freeman, Chief Engineer, Boston & Albany:

We cannot hold men without good, well-fitted, clean camps.

Earl Stimson, Engineer Maintenance of Way, Baltimore & Ohio:

The situation has come to such a point that laborers seeking employment inquire about all conditions of housing and feeding. Stationary camps equipped with good sanitary toilet facilities are a factor in holding men. At one point situated in a very busy industrial district we are able to compete with the abnormal rates paid for labor in manufacturing concerns by providing a modern stationary camp.

A. C. Mackenzie, Engineer Maintenance of Way, Canadian Pacific, Eastern Lines:

Our experience has been that where proper accommodations and other facilities are provided we can hold our men and also attract a good class of labor.

C. E. Weaver, Engineer Maintenance of Way, Central of Georgia:

Clean and well-kept camps unquestionably assist in holding labor, also the quality and quantity of food furnished. Probably there is not as much opportunity to get information of a comparative nature with negro labor as with white labor, as negroes ordinarily are not unusually particular about their quarters or food.

B. M. Cheney, General Inspector Permanent Way and Structures, Chicago, Burlington & Quincy:

It is the general opinion that good camps tend to hold the men, although at the present time it seems as though this does not have very much effect.

C. G. Delo, Chief Engineer, Chicago Great Western:

A good camp and good food will hold the men when wages are equal to those paid at other places. I do not believe the men will stay in any camp, regardless of how good the housing or the food, when the wages at another place are from 15 to 20 per cent. higher.

W. H. Penfield, Assistant to Vice-President, Chicago, Milwaukee & St. Paul:

There is no doubt but what, other conditions being equal, men prefer work at points where good living accommodations are provided. The benefits of good living accommodations, however, are not as apparent where transient or temporary forces are employed as they are where men are employed permanently, and perhaps have their families with them on the work. For all classes of permanent employes, much attention should be given their living facilities. Temporary employes will seek work where the best accommodations are provided, all other things being equal. They are really much more interested in the rates of wages and working conditions; the personality of the foremen and the character of the work to be performed, than they are of their living conditions. They feel that they are only temporarily located on the work, and probably do not give as much serious thought to the living accommodations as they would if permanently employed. Their object is to seek employment where they will receive a maximum wage with a minimum amount of work. All laborers demand reasonably good living accommodations. It is necessary to meet their demands in this respect. After this is done, it is questionable if any further refinement in living accommodations is reflected in work performed by the men.

C. A. Paquette, Chief Engineer, Cleveland, Cincinnati, Chicago & St. Louis:

The question of compensation seems to be the one uppermost in the minds of the men. In the large industrial centers reached by this road, the difficulty of holding men for track work, and, in fact, for any class of railroad maintenance work, is enormous. We are constantly scouring the contiguous territory for labor, but the percentage of men shipped to a job, who go to work, is very small. We make it a point to provide good accommodations and insist on good food being furnished the men, but notwithstanding all efforts along this line it is very difficult to maintain forces. The compensation offered the men in industrial work is very tempting, and they are prone to leave railroad employment for the industrial field no matter how well they are housed and fed by the railway company.

H. G. Clark, Assistant to Second Vice-President, Chicago, Rock Island & Pacific:

A good, clean, well-managed camp means better labor. Any money spent in improving facilities for employes is money well spent by any railroad.

A. J. Neafie, Principal Assistant Engineer, Delaware, Lackawanna & Western:

Good labor camps where men are properly handled and fed prove a good advertisement, which attracts and retains labor, this being noticeable with our test camp at Dover, N. J.

E. R. Lewis, Assistant to General Manager, Duluth, South Shore & Atlantic:

My experience is that the first requisite for a good camp is a foreman with sufficient intelligence and executive ability to preserve the best of discipline among his men. Next in importance is a sufficiency of good, clean, plain food. The latter is largely dependent upon the foresight of the person who does the ordering of the provisions. My observation is that men prefer to work in a well ordered camp where they get enough to eat, plain food well cooked and regularly supplied, rather than to work at a camp where the board is more abundant and costly and not so well served.

G. B. Owen, Superintendent of Maintenance, Erie:

The best inducement to keep the men now available for labor in camps is the fact that their meals are prepared and set for them. The standard sleeping car, well ventilated and sanitary, does much to hold good men in camps. Shower baths installed at some of the larger camps have produced good results.

J. R. W. Davis, Engineer Maintenance of Way, Great Northern:

Good camps attract laborers so long as these camps are better than the camps furnished by other railroads.

A. F. Blaess, Engineer Maintenance of Way, Illinois Central:

There is no question but that a clean, healthy, sanitary camp has much to do toward holding men and keeping them satisfied, and to keep them satisfied we must not only have good, healthy sanitary camps, but they must be well fed. We have given a good deal of attention in the past few years toward improving our camp cars, but there is a great deal more to be done to bring them up to the standard to which we expect to get them ultimately.

W. H. Courtenay, Chief Engineer, Louisville & Nashville:

My experience is that elaborate camps would have very little effect in holding men. Many of the negro laborers seem to prefer crowding in bunk cars to living in more comfortable houses. Negroes like to crowd together.

R. G. Kenly, General Manager, Minneapolis & St. Louis:

We believe the better the men are cared for the better work we get.

F. Ringer, Chief Engineer, Missouri, Kansas & Texas:

The maintenance of adequate and sanitary camps is, we think, very essential toward holding men, and it is our effort to provide satisfactory equipment in our extra gang outfits.

E. A. Hadley, Chief Engineer, Missouri Pacific:

There is no question but what the operation of first-class camp outfits will be a considerable aid in the securing and holding of laborers.

H. B. Reinsagen, Engineer Maintenance of Way, New York Central Lines:

Better camps will hold men; better rates of pay would help more, though care and attention are needed; the rate of pay is one ingredient in our problem; the kind of men we get is important, but we cannot choose. More attention must be given to this subject by our supervisors, which is new work to many of them. The class of labor we have is most disheartening; in many cases no rate of pay will hold them long, but we must depend on a reasonable wage and good treatment to hold the best of them and let the others go.

W. J. Backes, Engineer Maintenance of Way, New York, New Haven & Hartford:

Good camps are necessary to hold desirable men, but a certain proportion of those employed are drifters and will not stay long under any conditions. While our camps, generally speaking, are in good condition, they are not having an appreciable effect in holding the men any length of time. This is attributable to the scarcity and low class of labor we are obliged to employ, which it is believed would not remain in our employ, or anywhere else, longer than to earn a small amount of money. However, of all the labor we have employed recently, amounting to approximately 7000 men since February 1, 1917, there have been few if any complaints about the housing and boarding of the men. In fact, they praise our camp conditions.

W. R. Dawson, Assistant to General Manager, Norfolk & Western:

Men are better satisfied and are better physically fit to perform their work, and remain in the same service and location much longer.

T. H. Gatlin, Assistant to Vice- President, Southern Railway System:

There is no doubt whatever, that the furnishing of good comfortable camps, plenty of good food, and comfortable bedding is one of the best ways of holding negro labor, which we have been able to do in spite of the competition of local industries. Furthermore, our method of adding to the laborers' rate, the rate of his food and paying the commissary contractor, relieves the negro's mind of the idea that a deduction is being made from his pay, the deduction being a source of great uneasiness to the negro. Every pay day he gets his full day's wages clear, which tends to make him happy and contented. As a specific instance, we recently moved a force to build some cantonment tracks near a southern city, and instead of losing men were actually able to increase the size of the force by reason of the excellent living accommodations.

C. D. Purdon, Chief Engineer, St. Louis Southwestern:

It is impossible to secure or retain men unless camps kept in a clean and sanitary condition, and good wholesome food is furnished. A badly conducted camp is quickly advertised among the men over a wide territory and they refuse to ship out to such camps, while under ordinary conditions there is little difficulty in securing required number of men if camp conditions are proper.

Eastern Group **ADDENDA (1)**

Question Railroad	1	2	3	4	5	6
Baltimore & Ohio	Italian, Russian, Spanish, Greek, Negro, Native, Hobo. Few females for crossings.	Housing and food provided. Men inquiring about same.	Cars and bunkhouses—dining cars—showers, hot and cold water.	Steel bunks—mattresses—stationary tubs by Company.	Sanitation enforced. Pennsylvania regular medical examination.	Different methods Commissary Contract Stores selling supplies. Foreigners self-fed.
Baltimore & Ohio S. W.	Native and Negro. A few Italian, Greek and Austrian.	Housing — few exceptions feed Hobo and Negro.	Camp cars. Bunkhouses. Old buildings converted.	Bunks and ticks to all. Blankets to Native and Negro by Company.	Sanitary Regulations specified by Co. Relief Department.	Commissary Co. contract. Negro requires grocer credit. Foreigners self-fed.
Boston & Albany	Italian, Greek, Polack, Albanian, Russian, Negro, Native.	60% housing and feeding supplied.	Old coaches. box cars and bunk houses.	Steel bunks, mattresses and blankets by Company.	Some connected to town sewer. Sanitation enforced by Inspection.	Men self - fed. Agent at one point only.
Buffalo, Rochester & Pittsburgh	Italian, Russian, Polack, Austrian, Swedish, Negro and Native.	Housing and food for extra gangs and hobo.	Portable shanties, camps and cars.	Steel bunks, blankets and mattresses by Company.	Conform with State Sanitary Regulations. Foremen responsible.	Commissary Agent. Optional with men.
Canadian Pacific, Eastern Lines	Any available. Many Italian, some Japanese, few Negro.	Housing for all extra gangs. Food in unsettled territory.	Old box cars. Tents in summer in some locations.	Bunks — stoves by Company. Other equipment by men or contract.	No definite Sanitary Regulations. Governed by location or other conditions.	Sometimes by Commissary contractor, preferably left to men.
Central Railroad of New Jersey.	Some Native. Mostly Negro, Italian and Hungarian.	No camps at present.	Former camp cars obsolete.	Former cars were well equipped.	Sanitary arrangements possible in outlying districts.	Usually self-fed. Formerly Contracts.
Cleveland, Cincinnati, Chicago & St. Louis	Native, Hobo, Negro and some Foreigners.	Housing and food generally for extra gangs.	Houses for section help, camp cars and special buildings for extra gangs.	Bunks only by Company, Commissary or men furnish bedding.	No specific sanitary regulations. Men required to keep bunks clean.	Generally Commissary Contract Company feeds some Negro. Foreigners self-fed.
Delaware, Lackawanna & Western	Italian, Spanish, Poles, Hungarian, Negro and Native.	Housing for all but Native. Food in some cases.	Standard commissary—Bunk—Cook — and Mess cars.	Cars completely furnished by Railroad Company.	Cooks and assistants clean all cars. Fumigated each 3 months. Inspected.	Fed by general labor Foreman or self-fed.
Erie Railroad.	Italian, Native, Mexican, Negro.	75% of track labor housed.	Camp trains — Bunk cars on ground— Camp barracks for large cities.	Double - decked bunks by Company. Bedding by commissary or contractor.	Men who see that proper sanitation exists according to regulations.	Company Commissary — Labor contractor and self-fed.
Grand Trunk Railway.	Native, Italian.	Housing for all.	Principally box cars.	Bunks — Mattresses— stoves by Railway.	None.	Self-fed in all cases. Cook furnished by Company.
Kanawha & Michigan Railway.	Native, part Negro.	House one-half—other one-half live at home.	Box cars and old coaches converted. 2 permanent frame camps.	Wood and steel bunks. Men furnish bedding.	Portable privy. Supervisor responsible for clean camp.	Company pays cook. Foreman handles food.
Lake Erie & Western.	Native, Italian, Bulgarian, Roumanian, Greek.	Housing and food for all extra and some section gangs.	Temporary frame buildings and cars.	Steel bunks for all. Furniture and stoves for foreigners. Bedding for Native.		Men provide food. Divide expenses.

ADDENDA (1)

7	8	9	10	11	REMARKS
Annually contracted rate—deducted from pay. Notified when hired.	Good conditions keep men even in industrial localities.	Food and conditions subject to Railway Company's inspection.	Improving continually. Stationary camps being built.	Modern Camps hold men even against abnormal industrial rates.	Good general conditions draw and hold men.
Contracted rate deducted from pay.	Gets and holds floaters. Foreigners prefer self-feed.	Inspection of food and conditions by foremen and officials.	Constant repainting and disinfecting. Adding shower baths.	Improvements result favorably.	Prime factors holding labor (a) Rates, (b) living conditions. Best living conditions—best labor.
In one place: Men deal personally with agent.		No Company supervision except on complaint.	Old coaches instead of box-cars. Steel bunks. Insist on cleanliness.	Only clean, well fitted camps hold men.	Wages main item in holding men. Camps don't stop shifting.
Men pay $5 per week. Company pays Agent 5 cents per meal additional.	Good board holds hoboes.	Officials and foremen give meals close attention.	No Improvements being made.	Men want clean camps and good food at fair rate.	Hoboes prefer good food to showers and recreation rooms.
Board rates under supervision of general superintendent when used.	System not encouraged.	Board rates under general superintendent's supervision.	Not to any extent.	Proper accommodations attract good labor.	Proper accommodations hold men.
Left to commissary and men.	No comment.	Eng. Maintenance of Way had bunk houses and conditions inspected.	Bunk cars again being asked for due to high rent.	Good camps hold men but wages come first.	Nothing but good wages hold the men when labor becomes scarce.
Rate fixed by railroad through contract with commissary.	Contract better for railroad than own commissary. Self-fed men simpler for railroad.	Food output under contract supervised by railroad.	Old Pullmans and coaches being made into camp cars.	Wages the important item.	Good camps hold older men—all men seem to consider wages first. As yet no satisfactory solution.
Purchases from commissary car and board deducted from pay.	All camps satisfactorily handled.	Road masters check rates and food.	Test Camp at Dover, N. J., under general shop foreman.	Good camps—good advertisement. Notably Dover camp.	Camp Dover thoroughly modern. Hold men and get new men.
Rate determined by prevailing cost charged by week.	Commissary best regulated; open to losses by company. Contract best. Italians self-fed.	Track supervisors oversee food and rates. Rates established by prevailing costs.	Twenty new camps properly ventilated. Ten barracks. Old camps rebuilt.	Good meals, good beds and showers hold men.	
Method of charging left to foreman.	More satisfactory for men to feed self.	None.	More windows and steel bunks.	Only way to hold men is proper house and self-feed.	Railway carries all supplies for men. Ice, ice-boxes, water, etc., furnished.
Men pay for meals eaten. Deducted from pay, checked by supervisor.	System has worked well.	Supervisors eat at camps. No extortion allowed.	New cars have steel bunks. Fewer per car.	Good camps hold men. Foremen given charge. Good results.	Average meal 13 cents, good board. Have screens and clean camps. No drinking allowed.
				No effects noticed.	Believed that good camps would help hold labor.

Eastern Group—Continued **ADDENDA (1) Continued**

Question Railroad	1	2	3	4	5	6
Long Island Railroad.	Italian mostly, some Native.	House 75%.	Small buildings for cooking and sleeping.	Bunks and stove.	Provide small out houses kept clean by men.	Feed men in rare instances when held over.
Maine Central.	Mostly Native.	One-third to one-half provided housing.	Old passenger cars rebuilt.	Bunks — ticks, heavy blankets furniture, stoves, food, lockers and dishes by Company.	Bury refuse.	Foreman buys foods, cost divided.
New York Central	Native, South European Foreigners, Negro lately.	House nearly all.	Formerly cars only. Now also one-story frame houses.	Double-deck steel bunks now. Mattress and some blankets.	Bury garbage. Lime used in closet vaults.	White men board themselves. Foreigners and Negro fed by foremen under Company supervision.
New York, New Haven & Hartford.	White — mostly Irish. Many Negroes.	Housing for all.	Permanent camps, temporary camps and cars.	Bunks, some of steel. Mattresses, blankets.	Camps disinfected. Bedding washed. Difficult to keep camps sanitary.	Commissary department feeds men. Dining rooms, some with concrete floors.
New York, Ontario & Western.	Native and Italian.	75% housed and fed.	Box cars — Windows cut in.	Steel bunks by Company. Bedding by men.	Portable toilets. No other sanitary arrangements.	Men self-fed.
Norfolk & Western.	Native. Mostly Negroes.	Housing for all.	Camp cars, shanties, dwellings.	Bunks and wash basins and coolers.	Barrels for dumping refuse. Closets.	Boarding contractor.
Pennsylvania Lines (Southwest System)	Nearly all nations, Negro and Native.	Housing when required. Fed by Company.	Portable frame houses, having wash, laundry, dormitories, dining and recreation rooms.	Men assigned steel beds, mattress, blankets and pillows, when hired.	Dormitories scrubbed and sprayed weekly Formal regulation inspection by Company doctor. Men too	Company feeds men at cost.
Pere Marquette	Native, when possible. Foreigners otherwise.	House foreigners.	Bunk cars, kitchen cars, etc.	Wooden bunks and stoves by Company.	Division officers responsible for sanitation.	Men self-fed. Cars for cooking furnished.
Philadelphia & Reading	Negroes from Georgia.	Housed and fed.	Frame houses, papered and electric lighted.	Double decked iron beds—felt mattress and coverings by Company.	Frame privies, shower baths, stationary wash bowls, etc.	Company commissary for feeding or self-fed.

Western Group

Chicago, Burlington & Quincy.	Native when obtainable, Mexican, Negro and Foreigners.	Cars for extra gangs. Feed all but section forces.	Bunk cars, 2 or 3 bunk house camps.	Wood or steel bunks by Company. Mattresses and bedding by Commissary.	Commissary Company responsible to local officials for sanitation of camps.	Commissary Company feeds men. Few Negro camps self-fed on community plan.
Chicago Great Western.	Use all classes.	House Negroes, hobo and foreigners. Feed only large gangs.	Bunk cars when necessary to house.	12 wood bunks to cars. Bedding by men or contract.	Track foremen police camps every 2 days for sanitation.	Negro and hobo by contract. Foreigners usually self-fed.

ADDENDA (1) Continued

7	8	9	10	11	REMARKS
Company pays for these meals.			None.		No doubt interest shown in men is reflected in work. Also holds them.
Deducted from wages company pays excess of 50 cents per day per man.		Rates kept uniform. Complaints investigated.	None.		
Signal men pay each month. Brakemen each month. Italian and Negro board deducted.	Method used with white men is best. Negro and Italian do not stay.	Superintendent has charge. Works well. Men well fed. Rates held to cost.	Improving steadily. Coaches used, houses built, sanitation given.	Better conditions help. Pay main item.	Extra gang men have roving tendency. Good living conditions important. More thought, care and attention needed on this problem.
General manager sets rate. Deducted from pay.	Helps hold men. Outside feeding found unsatisfactory.	Charged $4 a week. After 4 weeks $3.50, at loss to company. Superintendent of dining cars in charge.	Permanent camps being built. Showers, toilets, etc. Concrete floor.	Good camps will not hold men long of type used, though camps please.	Bathing facilities required to prevent vermin. Bug squad for this. Men are well fed.
	Unwise to have contract commissary. Dissatisfaction.	No supervision.	No remodeling at present.		Men will not live in cars under present war conditions.
Two rates, different grades of food. Board deducted from pay.	Most satisfactory system. Not much trouble to railroad.	Division officials visit various gangs to oversee conditions.	Cars have been rebuilt and remodeled.	Men better fit physically and mentally if properly fed.	
Deducted from pay. Cost price charged.	Men are well fed and kept. Best system.	Wholesale price is charge made.	Camps kept thoroughly up-to-date.	Gets and holds men.	Some men will not stay under the best conditions.
No charges for [illegible]	Negro and hobo best to feed. Foreign better self-fed.	None.	Cars kept in good condition.	Good weather-tight cars required to hold men.	
Men allowed 50 cents per day extra if self-fed.	Men all company fed and well fed. No complaints.	Pay and rate for board fixed before hired. No trouble.	No change or required changes.	Not enough experience for opinion.	Men leave for industries close at hand when they learn of higher pay.
Agreement between company and commissary.	Commissary plan causes less friction than community plan.	Roadmasters must eat in camps and make reports frequently.	Steel bunks replacing wood. Screens and more windows.	General opinion that good camps hold men. Not so effectively just now.	
Rate determined by wages. Deducted from [illegible]	Few gangs. Therefore easily handled. No disadvantage noted.	Feeding supervised. No trouble.	No changes contemplated in providing labor.	Good camp holds men but wages is first item.	

Western Group—Continued **ADDENDA (1) Continued**

Question Railroad	1	2	3	4	5	[illegible]
Chicago, Milwaukee & St. Paul.	Native when possible, Italian, Greek, Bulgarian, Romanian, Armenian, Negro.	Houseforeigners. Negro, hobo. Hobo company fed. Others, self-fed.	Dwellings, bunk houses, cars, permanent camps.	Wood or steel bunksandstove. Bedding by contractor or men.	Pits for refuse. Water cars. Kept in clean, suitable locations.	St. Paul Companyfeeds hobo gangs. Others self-fed.
Chicago, Rock Island & Pacific	All kinds, Negro, Mexican, Hobo, foreigners.	Housing for all but Natives.	Section houses, cars, bunk houses, 1 camp.	Wood and metal bunks by Company. Bedding by J. S. Grier Company.	Monthly camp inspection by Company surgeons of all housing.	Contract with J. S. Grier for board.
Duluth, South Shore & Atlantic.	Native.	House and feed extra gangs.	Cars — office, lounging, sleeping, dining.	Stoves — double deck wood bunks, pillows, blankets and cooking utensils.	All refuse burnt or buried. Portable latrines. Wire screens furnished.	Contract for food. Company pays cook, etc. Bridge and building gangs communityfed.
Elgin, Joliet & Eastern.	Native obtainable. Mostly Italian. Some other Foreigners.	Housing. No food.	Bunk cars—old box cars. Car for foreman and timekeeper.	Steel bunks and one stove.	Portable toilets. No other sanitary improvements.	All men self-fed through agents in Chicago.
Great Northern.	Native, Italian, Greek, Turk, Austrian, Bulgarian, Macedonian, Mexican, Japanese, Chinese, Hindu, Russian, few Negro.	All but Natives housed. Natives fed by contract.	Box cars converted to sleeping, dining, office.	Men furnished bedding.	Cars sprayed monthly with antiseptic.	Foreigners self-fed. Natives fed by contract or Company Commissary.
Illinois Central.	South of Ohio River 85% Negro, 15% Native. North of Ohio River, Italian, Greek, Negro, Native and Hobo.	Housing for all. Few recent Company commissaries.	Cars. Some temporary buildings.	Bunks (steel), some mattresses.	Bedding aired twice a week Toilets. Inspection by supervisor regulations.	Foremen take care of feeding.
Northern Pacific.	Mostly Italian and Greeks.	Housed.	Bunk Cars.	Wood bunks. No bedding by Company.	Careful with drinking water. No other regulations.	Self-fed.
Minneapolis & St. Louis.	Native Greek, Italian, Mexican, Hobo.	Housing for all.	Box cars.	Bunks. Bedding contract or by men.	Sanitary regulations limited.	Native and hobo by contract. Foreigners self-fed.
Missouri Pacific.	Native for sections, Negro for south, Italian and others for north.	Housing for sections. House and food for all others.	Dwellings for sections. Cars for moving gangs.	No bunks or bedding furnished regular sections. Extra gangs bunks.	Division Superintendent responsible for sanitary regulations.	Contract for feed.
St. Louis-San Francisco.	Prefer Native. Must use Negro and foreigners.	House and feed all extra and construction gangs.	Outfit cars, tents and temporary frame structures.	Steel bunks and bedding by board contractor.	Up to board contractor. Inspection made by railroad. Careful selection of camp site.	Contracted.

ADDENDA (1) Continued

7	8	9	10	11	REMARKS
Contracted rate deducted from wages weekly for food and bed.	Foreigners will not work if company fed. This relieves company contract, also relieves company	Rates contracted. Food supervised. This is necessary.	Much attention is now given living conditions of labor.	Transients consider maximum wages and minimum work. Permanent men, living.	All men demand reasonable living conditions. After this point is reached work reflects no further improvement.
Rate determined by pay and cost of food supplies at present $4.50.	System very advantageous to railroad company. No disadvantage.	Surgeons also inspect food. Roadmaster also makes inspection.	Not much improvement has been made.	Good clean, well managed camp holds best labor. Money well spent by railroad.	Well kept men attract other good men. Good tools secure good labor.
Prorate system used. Average 20 cents per meal. Deducted from wages.	Community fed least trouble for company. More economical.	Company checks contract system and condition of cars. No accounts taken of community plan.	Trying to keep down cost of board rather than raise wage.	Good food, clean camp and intelligent foreman hold men.	Men prefer clean, good food at low rate to fancy food at high rate.
Up to men.	Self-fed men most advantageous to company.	None.	None.	No improvements made.	None.
Rate contract. Rate depends on wage. $2 per day, $5 per week board.	Most satisfactory to have self-fed men.	Company reserves right to inspect kit and food.	No recent changes.	Best camps attract labor.	Good beds and food offset low wages, even in face of high wage.
Watched by railroad. Foremen deduct from wages — limit 65% of wage.	Small gang foremen feeding best. Large gangs contract feed.	Supervisors check foremen. Engineer Maintenance of Way contracts rate with commissary.	All cars are being improved.	Good feed, good beds and camps hold men.	Special camps built in Wildwood, Ill. Electric lights, water, etc.
	Self-fed system satisfactory.	No boarding outfits.	No general work being done.		
Rate determined by general manager through contract. Deducted from pay.	No advantages either way.	Track superintendent inspects food.	No recent changes.	Better care, better work.	
Contracts let on competitive bids. Deducted from pay.	No trouble either way.	Division superintendent oversees food and sanitary conditions.	All suggestions for improvements given test. Improvements constantly going on.	No doubt but that good conditions get and hold labor.	No liquor allowed. Contract furnished labor—in return for profit on food for men.
Rate agreed by company and contractor deducted from pay.	Best system. Contractor keeps camps full.	Inspected by railroad officials. No change of rate without railroad authority.	No changes. Present system O. K.	Good camps necessary. Men will advertise poor camps.	Our system best for railroad. No manipulations by foremen.

Western Group—Continued **ADDENDA (1) Continued**

Question Railroad	1	2	3	4	5	6
Southern Pacific.	Native, Italian, Greek, Austrian, Japanese, Chinese, Mexican.	House all. Feed Caucasians only.	Cars and camps.	Bunks by company. Bedding by men.	Sanitation as per State Housing Commission.	Contract.
Salt Lake Route.	All Mexican, except few Americans.	House all foreigners.	Frame and concrete dwellings for section. Tents and cars for moving gangs.	Bunks.	Permanent camps and dwellings have pipe lines, concrete cisterns. Water cars.	2 stores furnish supplies. Reasonable free transportation.

Southern Group

Central of Georgia.	Nearly all Negroes.	On extra and bridge gangs, house and feed all.	Camp cars.	Wood or steel bunks and mattresses by Company.	Portable toilets, lime for disinfecting same. Barrels for refuse. Camp kept clean.	Foreman has charge of board.
Louisville & Nashville.	Native white and Negro.	Housing for nearly all.	Good house for foreman. Houses and cars for labor.	Bunks. Men provide bedding.	Privies built at section houses. None with gangs.	Foremen feed men. Section men self-fed.
Nashville Chattanooga & St. Louis.	Negro and Native Anglo-Saxon.	House normal gang. Pay foremen rent. Board nearly all.	Old box cars; Section houses specially built.	Wooden and steel bunks.	Sanitary closets. Concrete capped wells with pumps. Refuse buried. Cars screened.	Company feeds men. Charged actual cost and cook's wage.
Norfolk Southern.	Negroes.	All extra gangs.	Cars.	Bunks by Company. Bedding by men.	Trenches for refuse. Privies shifted when required.	Contract.
Seaboard Air Line.	95% Negro, 5% Native.	Section men housed. Extra gangs in cars.	Cars and coaches, frame houses.	Beds and bedding by men. Extra gangs furnished bunks.	No regulation.	Bridge & Building, self-fed. Others contract fed.
Virginian Railway.	Native, Negro, Italians.	Housing for all.	Shanties. Foreman, houses. Camp cars.	Sanitary bunks. No bedding or cooking utensils.	No sanitary regulations.	By contract Self-feeding.
Southern Railway.	Native, Negro. Arranging for Porto Ricans.	Dwellings for section men. Extra gangs in camp cars.	Extra gangs in camp cars. Section labor in section houses.	Extra gangs furnished bunks and bedding.	Commissary inspects and disinfects, cleans and ventilates.	Extra gangs by contract.
Atlantic Coast Line.		Housed.	Shanty cars.	Steel bunks by Company, bedding by men.	-	
Richmond Fredericksburg & Potomac.	Two-thirds Negro, one-third White.	House all.	Bunk houses and cars, old sleepers.	Steel bunks, bedding, stores, etc., by Company.	Toilets — with water, sewer when possible. Foreman held for sanitary conditions.	Company sells men food supplies, cook furnished by Company.

ADDENDA (1) Continued

7	8	9	10	11	REMARKS
Rate agreed on by railroad and contractor.	Greater economy by contracting system	Contracts terminate on short notice. This insures quality and quantity of food.	No change.	Good camps, low board hold men.	
Railroad company supervises rates.		Railroad supervises rates.	None.	Believe in good camps.	
Cost prorated among gang. Deducted from wages.	Smooth running system. Supervision required to prevent abuses.	Occasional inspection made of food and rate. At present 30 cents to 40 cents per day.	No changes recently made or contemplated.	Clean and well kept camps undoubtedly help hold men.	Not much information obtainable for comparison with Negro labor. Negro not so particular.
Railroad limits rate. Deduct from wages.	Self - fed men better for company.	Track superintendents oversee quality and quantity of food.	In few exceptional cases railroad company has fed men.	Large camps will not hold Negro labor. Prefer crowding.	With white men better conditions help.
Board rate fixed few years ago. Deducted from pay. No charge on rainy days.	Keeps men better fed and satisfied than contract or foreman fed.	Rate computed several years ago, not raised. Men well fed.	Putting in steel bunks and sanitary closets.	Have loyal, well fed men. Gangs always full strength.	Recently due to competition by industry have had some trouble holding men.
Rate and food settled by agreement with contractor.	Formerly company fed men. Present system better.	Rates and food subject to railroad company's inspection.	Cars well equipped. Commissary for clothing and supplies on cars.	Good results obtained.	
Rate is prorated and deducted from pay.	For extra gangs prefer contractor.	Foremen watch food. Works well. Rates set by contractor.	No recent changes. Much room for improvement.	Negro labor require waterproof car kept warm in winter.	Division engineers and road masters required to inspect camps frequently.
Board deducted from wages.	Exercise no supervision while men are satisfied.		All cars have been rebuilt. Some new cars.		
Contract price—paid by company.	Contract system best for large floating gangs.	Feeding inspected by officials who make regular report.	Plans being prepared for remodeling cars.	Good camps will hold men. Model camp now used.	No trouble holding labor in model camp.
Accounts deducted from pay.	This gives men credit otherwise not obtained.	Company guards men from too high prices.	Remodeling bunk houses.	Good camps hold men.	Men say they appreciate improvements and remain with Company in face of higher wages.

Addenda (2).

ADDITIONAL COMMENTS.

The following additional comments bear on the general subject of Housing and Feeding Laborers:

E. G. Lane, Engineer Maintenance of Way, Baltimore & Ohio, Western Lines:

The prime factors in securing labor necessary for track maintenance are (a) the rate paid and (b) living conditions. The improvement of either condition tends to add to the available labor. The improvement of the latter has a definite effect in holding labor which has been extremely nomadic in its tendencies for the past eighteen months, for the two reasons cited. We continually impress upon all concerned in the maintenance of way department the necessity of providing accommodations with the necessary conveniences so that reasonably proper living conditions will result, that meals will be provided, where commissary companies are employed, with regularity, and that sleeping quarters will be kept in a sanitary condition so as to insure men securing proper rest. Where this accomplishment has been best effected, labor conditions are most satisfactory, although at no point at the present time, except a few, have we sufficient labor.

F. B. Freeman, Chief Engineer, Boston & Albany:

The camps do not seem to stop the constant shifting of men. The railroad paying the lowest rate of wages for labor only get the poorest, who will not stick long on any job.

E. F. Robinson, General Manager and Chief Engineer, Buffalo, Rochester & Pittsburgh:

It is our opinion that good, clean camps and surroundings, with good board at a nominal rate, are more attractive to men of this class than shower baths, recreation rooms, etc.

H. G. Clark, Assistant to Vice-President, Chicago, Rock Island & Pacific:

The railways would be well warranted in spending considerable money in the improvement of boarding facilities for extra gangs and section labor. A well-housed, well-fed extra gang will not only be kept filled up, but will always attract the best men, and such men will undoubtedly do considerably more work. Good tools and good boarding facilities are the best means of obtaining an ample supply of labor, and railroads that do not give this such attention are not securing an adequate supply. The difficulty with large western railroads is that their work is scattered over such a large territory that permanent camps are, generally speaking, impracticable. Such roads must, therefore, depend upon the use of bunk cars which, when properly equipped and kept sanitary, with good feed, will attract labor to same.

E. A. Hadley, Chief Engineer, Missouri Pacific:

No deduction is made from the laborer's wage for securing work, nor is any bonus paid to the contractor for the securing of laborers, his entire profit coming from the boarding of the men. Transportation is furnished to the contractor wherever consistent with legal obligations, and he is required to place a man in charge of each shipment of laborers, to see that they go through to their destination. The contractor is required to pay freight and express at tariff rates, on all shipments of commissary goods, and he is also required to reimburse the railroad under current M. C. B. rules for all damage to the outfit cars. In placing these cars on spur tracks, kitchen, dining and other cars are spaced at least 30 ft. from the bunk cars. Under the terms of the contract the contractor is not allowed to dispose of any intoxicating liquors at any of the camps.

E. D. Levy, Vice-President and General Manager, St. Louis-San Francisco:

Opposed to the practice of gang foreman boarding the men or running commissaries as it is an invitation to manipulate them. By having this feature taken care of by an outside concern the railway representative and the boarding company representative check against each other.

Addenda (3).

A MODERN CAMP ON THE BALTIMORE & OHIO.

By Earl Stimson,
Engineer Maintenance of Way, Baltimore & Ohio.

A stationary boarding camp has recently been constructed at Folsom, Pa., which is typical of our modern camp construction. It consists of two bunk houses, a boarding house, two toilet rooms and a shower bath. The bunk houses are each 20 ft. by 60 ft., one being used for colored and the other for white laborers. A small room 18 ft. by 18 ft. is partitioned off in the white bunk house for the use of the foremen. Twenty-four double deck steel beds are used in each bunk house, thereby accommodating a total of 96 men, including foremen. Windows and doors are well screened. Combination felt and straw mattresses are used, the blankets being furnished by the commissary company. The boarding house is 60 ft. by 20 ft., the front of which is used by the commissary company as a store where the men may buy tobacco, underwear, shoes, clothing, etc. In accordance with the contract with the commissary company, the prices charged for these articles are in accordance with prevailing prices in that vicinity.

The dining room is in the middle of the building and is 30 ft. long. Two long wooden tables (one used by white men and the other by colored), at each side of the room with wooden benches, comprise the furniture. The tables are covered with white oil cloth, the food is served on the table in large platters or porcelain pans and the men help themselves. Two meals are served each week day by the commissary company and the men are furnished with lunches, which are carried with them on the work. Three meals are served on Sunday.

The kitchen (13 ft. by 20 ft.) is in the rear of the dining room and is equipped with running water furnished by the railroad. In the rear of the kitchen is a small lean-to 11 ft. by 12 ft. used as a bunk house for the cook. An ice box and small slatted box are built on the side of the building next to the kitchen to keep perishable vegetables.

About 30 ft. in the rear of the bunk houses is a wooden wash table provided with tin wash basins. A double water faucet at each end furnishes the water. A shower bath is provided which consists of a small enclosure boarded with a water spigot about 8 ft. above the floor. Attached to this spigot is a bucket with a perforated bottom which furnishes the shower. This is very popular with the men and is much used.

A pit toilet divided into two parts (one for white and one for colored men), with housing is located about 60 ft. in the rear of the bunk houses. A separate toilet is also provided for the commissary employés.

Addenda (4).

COMPANY OPERATED BOARDING CAMPS ON THE NEW HAVEN.

By W. J. Backes,

Engineer Maintenance of Way, New York, New Haven & Hartford.

None of our new permanent camps have yet been entirely completed and sanitary regulations, therefore, could not well be enforced, so far as laborers are concerned. Complete freedom from vermin can be obtained only where men take care of their own persons, and this cannot well be done without bathing facilities and privacy. With proper facilities and accommodations and a desire on the part of the laborers to keep clean, very little trouble should be experienced with vermin, or spread of disease. So far we have had no trouble except with bedbugs at a few points where old cars are used, and there is a bug squad to cover such points.

The class of men employed are fed better than they were at boarding houses and in their own homes before they were employed by this company, and we believe that if it were not for the great scarcity of labor which makes it necessary to employ everything that comes along, our camp conditions, as they are now maintained, would be a special inducement for the ordinary laboring man to remain with us. The cost of food per meal for the month of April, 1917, at some of the camps was as follows:

New Haven	19.3 cts.
Derby Junction	16.8 "
Putnam	17.0 "
Waterbury	25.2 "
South Norwalk	18.0 "
Midway	14.7 "
Plainville	22.2 "
East Hartford	17.2 "
Maybrook	22.4 "

During March and April the average cost of food at all camps was 18.5 cents per meal. The cost varied at different camps from 14.7 to 25 cents, owing to irregular feeding at some camps and a very small number of men at others. The total cost per meal, including labor, janitor to look after sleeping accommodations, fuel, ice, washing of blankets, etc., was about 27 cents.

At Harlem River, N. Y., the food furnished to 214 men on the transfer tugs and the cost for food and labor in buying and delivering to boats for the month of May was 61 cents per man per day. The laborers are fed bacon and eggs, baked beans and frankfurters, bread and butter and coffee for breakfast. At some camps lunches are put up consisting of three or four sandwiches, ham, roast and corned beef. Dinners consist of roasted meats, pork, beef, veal stew and vegetables, with bread and butter and coffee; fish is usually provided on Friday. Of these various kinds of meats the men consume about 1½ lbs. each per day. They are not restricted as to quantity, and are served all they wish.

The number of employés fluctuates constantly. It has been noted that new men arriving eat more the first few days. Only one kind of meat is cooked for each meal and it is served on an individual plate, but second portions are served as requested. As it is perhaps generally understood when men subsist themselves, they will get along with cheaper grades of food than they expect to be furnished by the railroad company.

With the number of men at all camps fluctuating from full capacity to 25 per cent. of capacity, there is of course waste of food and also the cost of cooks and waiters is high. A camp feeding 30 men regularly could be taken care of by two men; a camp of 60 people by three men and of 100 people by four men, and these men could look after sleeping accommodations as well as feeding.

The prices of foodstuffs are very high at present and the advance in the cheaper grades of meats has been much greater than in the better grades. Butter and potatoes are also high and if men are given all they wish to eat and of a good quality, the cost of meals as given above probably cannot be reduced until prices for foodstuffs are lower.

Addenda (5).

LAWS IN THE VARIOUS STATES COVERING THE HOUSING AND CARE OF EMPLOYES IN MAINTENANCE AND CONSTRUCTION CAMPS.

Connecticut.

Inspection of lodging houses. Every agent of a firm or corporation and every other person who shall maintain or have charge of any structure used as a boarding house or place of abode for laborers employed by such person, firm or corporation, shall within seventy-two hours after such structure has been occupied for such purpose or purposes notify the health officer of the town, city or borough, in which such structure is located. Such health officer within five days thereafter shall inspect such premises and may forbid the use of the same altogether, or make such other orders as he may deem necessary to protect the health of the inmates. Every person violating any provision of this section or failing to comply with any order of a health officer made pursuant to this section shall be fined not more than one hundred dollars.

Lodging house or boarding house, meaning "any house or building, or portion thereof, in which six or more persons are harbored, received, or lodged for hire, or any building, or part thereof, which is used as a sleeping place or lodging for six or more persons not members of the family residing therein." This definition includes maintenance and construction camps.

Every tenement, lodging or boarding house, and every part thereof, shall be kept clean and free from any accumulation of dirt, filth, garbage or other matter, in or on the same, or in the yards, courts, passages, areas or alleys in connection with or belonging to the same. The owner, tenant, lessee or occupant of every tenement, lodging or boarding house, or part of such house, shall cleanse thoroughly all rooms, passages, stairs, floors, windows, doors, walls, ceilings, privies, water-closets, cesspools, drains, halls, cellars, roofs and other parts of such house or the part of such house of which he is the owner, tenant, lessee or occupant, to the approval of the board of health, and shall keep the same in a cleanly condition at all times.

Every owner of every tenement house shall provide, for such building, suitable receptacles for, or convenience for the disposal of garbage, ashes and rubbish.

Whenever any tenement, lodging, or boarding house, or any building, structure, excavation, business pursuit, matter, or thing in or about such house or the lot on which it is situated, or the plumbing, sewerage, drainage, light, or ventilation of such house, is, in the opinion of the board of health, in a condition which is, or in its effect is, dangerous or detrimental to life or health, said board may declare that the same, to the extent specified by said board, is a public nuisance, and may order the same to be removed, abated, suspended, altered, or otherwise improved or purified, as the order shall specify. The board of health may also order or cause any tenement house, or part thereof, any excavation, building, structure, sewer, plumbing pipe, passage premises, ground, matter, or thing in or about a tenement, lodging, or boarding house or the lot on which such house is situated, to be purified, cleansed, disinfected, removed, altered, repaired, or improved. If any order of the board of health is not complied with, or so far complied with as said board shall regard as reasonable, within five days after the service thereof, or within such shorter time as said board shall designate, then such order may be executed by such board, through its officers, agents, employes, or contractors.

Whenever it shall be certified by the board of health that a tenement, lodging, or boarding house, or any part thereof, is infected with contagious disease, or that it is unfit for human habitation or dangerous to life or health by reason of want of repair or of defects in the drainage, plumbing, ventilation, or construction of the same, or by reason of the existence on the premises of a nuisance liable to cause sickness among the occupants of such house, the board of health may issue an order requiring all persons therein to vacate such house, or part thereof, within not less than twenty-four hours nor more than ten days, for the reasons mentioned in such order. In case such order is not complied with within the time so specified, the board of health may cause such house, or part thereof, to be vacated. The board of health, whenever satisfied that the danger from such house, or part thereof, has ceased to exist, or that such house is fit for human habitation, may revoke such order, or may extend the time within which the same may be complied with.

If a room in a tenement, lodging, or boarding house is overcrowded, the board of health may order the number of persons sleeping or living in such room to be so reduced that there shall not be less than five hundred cubic feet of air to each adult, and three hundred cubic feet of air to each child under twelve years of age, occupying such room.

Every building used as a tenement, lodging, or boarding house shall be furnished with adequate and suitable privy vaults or water-closets. There shall be at least one such closet or vault for every two apartments of three rooms, or less, each, and one such closet or vault for every apartment of four or more rooms. The vaults, privies, or water-closets in or belonging to any tenement, boarding, or lodging house located on premises abutting on any street or alley through which there is a sewer with which connection may be had shall be connected with such sewer by the owners, lessees, or agents of such property, whenever so required by an order of the board of health. In every tenement, lodging, or boarding house having running water and a sewer connection, and which is three or more stories in height, the water closets required for the occupants of the third and higher stories shall be located on or above the third floor of such house. Every bathroom or water-closet compartment in a tenement, lodging, or boarding house shall be ventilated by an outside window, or a window opening upon a vent shaft, or by a separate ventilating flue, of non-corroding material and at least thirty-six square inches in area, leading directly to the roof; and every such bathroom or water-closet compartment, not otherwise sufficiently lighted, shall be provided with light from an adjoining room or rooms by means of translucent glass, of adequate size, in a fixed sash.

Pennsylvania.

In Pennsylvania such matters would be taken care of by the local boards of health, who always have the power to abate nuisances.

The Act of July 24, 1913, P. L. 1015, provides for the establishment in the State Department of Health, of a Housing Bureau. Section 2 of the Act, which sets forth the duties of this bureau, reads as follows:

"118. It shall be the duty of said bureau to investigate the sanitary conditions of tenement, lodging, and boarding houses, and when the same are found, in the opinion of said bureau, to be a menace to those occupying the same, or employed therein, or to be overcrowded, to condemn the same, and to notify the owners or agents thereof in writing, setting forth the unsanitary or overcrowded conditions thereof, and specifying in writing the changes or alterations which shall be made thereto for the purposes of relieving such conditions, and further specifying the time within which such changes or alterations shall be completed or overcrowding relieved."

Labor camps, etc.

Sec. 18. The commissioner shall inspect all labor camps and housing accommodations for employes, maintained directly or indirectly in connection with any work or place where work is being performed, and all places established for the temporary shelter and care of aliens and unemployed persons, and prescribe minimum standards of sanitation for all such labor camps, accommodations and temporary quarters.

New Jersey.

We cannot find any Statute in the State of New Jersey which deals specifically with the matter of housing and caring for all men in boarding camps maintained by railroad companies and contractors. The matter is probably governed by the "Health" law of New Jersey. Under this statute the State Department of Health is created and this department has formulated what is known as the State Sanitary Code. This Code is quite broad in its nature and deals with questions of sanitation generally throughout the state. The "Health" law also empowers the creation of local Boards of Health by the various municipalities and authorizes such local boards of health to pass ordinances and make rules and regulations in regard to public health for a number of purposes, among which are the prohibition and removal of any offensive matter or the abatement of any nuisance in any public highway, road, street, avenue or alley, or other place, public or private, and cause the removal thereof at the expense of the owner. Also the regulation of sanitary condition of tenement houses, jails and public buildings.

Sanitation of Camps Occupied by Migratory Workers:

(Amendment No. 4 to Interstate Quarantine Regulations, 1916.)
Public Health Service.

which reads as follows:

"To medical officers of the U. S. Public Health Service, State and local health authorities, and others concerned.

The following addition is hereby made to the Interstate Quarantine Regulations promulgated by this department January 15, 1916, said addition and regulations being in accordance with the act of Congress approved February 15, 1893.

The following regulation, section 37, is hereby added to the Interstate Quarantine Regulations:

Section 37. Persons, firms, or corporations maintaining camps of migratory workers shall at all times maintain such camps in a proper sanitary condition and shall take proper measures to maintain the camps so occupied in a vermin-free condition and shall exercise such other precautions as shall prevent the interstate spread of disease from such camps, and the Surgeon General may from time to time detail officers or employes of the United States Public Health Service to make such inspections as shall be necessary for the enforcement of this regulation."

Massachusetts.

There is nothing in the laws that refer to labor camps alone, but the roads are expected to conduct them in a seemly manner, and if they fail to do so the Board of Health would get after them and issue orders with which they would have to comply.

Drinking Water: All industrial establishments within this Commonwealth shall provide fresh and pure drinking water to which their employes shall have access during working hours. Any person, firm.

association or corporation owning, in whole or in part, managing, controlling or superintending any industrial establishment in which the provisions of this section are violated shall, upon complaint of an inspector of the State Board of Labor and Industries, of the Board of Health of the city or town, or of the selectmen of the town in which the establishment is located be punished by a fine of one hundred dollars for each offence.

Toilets to be Provided: In every factory, workshop, manufacturing, mechanical, mercantile or other establishment, there shall be provided suitable, adequate and convenient water-closets and washing facilities, separate for each sex and plainly so designated, of such number, in such location and so constructed, lighted, ventilated, arranged and maintained as may be determined by such reasonable rules and regulations as the State Board of Labor and Industries may adopt with reference thereto. No person shall be allowed to use a closet or privy which is provided for the use of persons of the opposite sex. If any such establishment is so located that a connection with a sewer system is, in the opinion of the said board, impossible or impracticable, it shall provide such suitable toilet and washing facilities as may be required by the said board.

New York.

There are no laws in this state relating to the housing and care of employes in maintenance and construction camps. The Public Health Law, however, while not specifically referring to such camps, undoubtedly would affect them and would place in the jurisdiction of local boards of health in cities, villages and towns any question as to proper sanitary and hygienic regulations of such camps.

Michigan.

Act. No. 3. This act amends 17, act No. 285, Acts of 1909, by adding thereto the following: Where railway cars are used for sleeping or living accommodations or where other premises for sleeping or living accommodations are furnished by any employer or his agent, for men or women engaged in the construction of railroads or other work, such cars or other premises shall be maintained in a cleanly and sanitary condition and kept sufficiently heated and well lighted and ventilated and a separate place and facilities shall also be provided for the purpose of drying clothes.

Any firm, person or corporation or any agent or foreman thereof, or any contractor or other person who has control over such conditions, may be prosecuted at the instance of the factory inspector or other proper authority when there occurs a violation of this section with respect to the conditions specified therein, over which such person, firm or corporation has control. It shall be unlawful for any employe to do anything to hinder or make difficult, compliance with this section: Provided, that the provisions of this section shall not apply to railway sleeping cars used exclusively for the transportation and accommodation of passengers carried by said railways.

California.

Acts of 1915. Chapter 329. Sec. 1. An act * * * (chapter 182, Acts of) 1913, is hereby amended to read as follows:

Sec. 1. In or at any camp where five or more persons are employed, the bunk houses, tents, and other sleeping places of such employes shall be kept in a cleanly state, and free from vermin and matter of an infectious and contagious nature, and the grounds around such bunk houses, tents, or other sleeping places shall be kept clean and free from accumulations of dirt, filth, garbage and other deleterious matter.

Sec. 2. Every bunk house, tent or other sleeping place used for the purpose of a lodging or a sleeping apartment in such camp shall contain sufficient air space to insure an adequate supply of fresh air for every person occupying such bunk houses, tent or other sleeping place. The bunks or beds shall be made of iron, canvas or other sanitary material, and shall be so constructed as to afford reasonable comfort to the persons occupying such bunks or beds.

Sec. 3. Every mess house, dining room, mess tent, dining tent, kitchen, or other structure where food is cooked, prepared or served in such camp shall be kept in a clean and sanitary state and the openings of such structures shall be screened.

Sec. 4. For every such camp there shall be provided convenient and suitable privy or other toilet facilities, which shall be kept in a clean and sanitary state. A privy other than a water-closet shall consist of a pit at least two feet deep, with suitable shelter over the same, and the openings of the shelter and pit shall be enclosed by screening or other fly netting. No privy pit shall be filled with excreta to nearer than one foot from the surface of the ground and the excreta in the pit shall be covered with earth, ashes, lime or other similar substance.

Sec. 5. All garbage, kitchen wastes and other rubbish in such camp shall be deposited in suitable covered receptacles which shall be emptied daily or oftener if necessary and the contents burned or otherwise disposed of in such a way as not to be or become offensive or insanitary.

Sec. 6. It shall be the duty of any person, firm, corporation, agent or officer of a firm or corporation employing persons to work in or at such camps to which the provisions of this act apply and the superintendent or overseer in charge of the work in or at such camps to carry out the provisions of this act.

Sec. 7. The Commission of Immigration and Housing of California shall administer this act and secure the enforcement of the provisions thereof, and for such purposes shall have the right to enter and inspect all camps to which the provisions of this act apply. Any camp coming under the provisions of this act which does not conform to the provisions of this act is hereby declared a public nuisance, and if not made so to conform within five days, or within such longer period of time as may be allowed by the Commission of Immigration and Housing of California, after written notice given by said commission, shall be abated by proper action brought for that purpose in the Superior Court of the county in which the camp or such greater portion thereof is situated.

Sec. 8. Any person, firm, corporation, agent or officer of a firm or corporation, or any superintendent or overseer in charge of the work in or at any camp coming under the provisions of this act, who shall violate or fail to comply with the provisions of this act, is guilty of a misdemeanor, and shall, upon conviction thereof, be punished by a fine of not more than two hundred dollars, or by imprisonment for more than sixty days, or by both such fine and imprisonment.

Washington Regulations.

The commissioner of health of the state of Washington has prepared a set of rules and regulations governing sanitary conditions in industrial camps in that state, of which the following is an abstract:

1. Hereafter contractors and all other persons who may establish an industrial camp or camps for the purpose of logging or any like industry or for the purpose of constructing any road, railroad or irrigation canal, or other work requiring the maintenance of camps for men engaged in such work, or any other temporary or permanent industrial camps of whatsoever nature, shall report to the state commissioner of health so as to maintain good sanitary conditions, and shall at all times keep such

camp or camps in a sanitary condition satisfactory to the state commissioner of health.

2. The health officer of each county shall report to the state commissioner of health on the location and sanitary condition of all industrial or construction camps within his jurisdiction in the month of June each year, and at such other times as the commissioner of health may require.

3. All contractors and other persons responsible for the control and management and construction of industrial camps must use all reasonable precautions to protect the men in their employ from disease, and to that end they shall comply with the following regulations adopted by the state board of health.

4. The following are the instructions and recommendations relative to the proper sanitation of camps. The natural topography of the land where camps must of necessity be located renders it impossible to specify in detail complete plans for temporary camps, but the management of camps will be held strictly responsible for failure or refusal to comply with the general intent and spirit of these regulations:

(a) Camps must be established upon dry, well-drained ground.

(b) All natural sink holes or collections of pools of water must be drained and filled when the camp is first established.

(d) The toilets must be located convenient to the bunk houses, and as far removed from the kitchen and eating house as may be practicable.

(e) The use of toilets provided for the men must be made obligatory, and instant discharge of any employe polluting the soil in the camp must be rigidly enforced.

(f) In camps of 100 or over there must be one employe whose principal duty shall be to act as scavenger and garbage collector.

(h) All toilets in the camp must be fly-proof. (The state board of health will furnish drawings of inexpensive fly-proof toilets upon request.)

(i) The kitchen and eating house must be effectively screened against flies.

(j) Garbage must be collected in tight cans and burned or buried daily. Garbage may be fed to pigs provided the pen is located not less than 100 ft. from the cook or eating house and kept in a sanitary condition.

(k) Tin cans and other non-inflammable refuse must be collected daily and burned over every ten days or buried in a pit.

(l) Food supplies must be carefully screened and thorough and systematic scrubbing of kitchen, eating houses and bunk houses must be observed.

(m) The supply of water for the camp must come from an absolutely uncontaminated source.

(n) Care must be taken not to pollute the water supply of another camp or the water supply of any of the people of the State of Washington.

(o) All sick from whatever cause should be isolated from the remainder of the crew immediately.

(p) All persons engaged in the care of the premises and handling of the food, particularly cooks and helpers, should be carefully examined and particular attention paid to the point as to whether or not they have suffered from typhoid fever within recent years.

Addenda (6).

SANITATION INSTRUCTIONS, ILLINOIS CENTRAL RAILROAD COMPANY.

Office of Chief Surgeon.

Chicago, September 1, 1912.

To Road Masters, Section Foremen and Those in Charge of Surveying Parties:

1. In locating bunk cars the highest ground available should be selected in order to prevent disease from accumulated water. Any depressions in which water will accumulate should be drained or filled with cinders. If it is not practicable to drain stagnant water near bunk cars, or to fill depressions, oil should be placed on these pools at least once every two weeks.

2. As soon as site is selected, immediately build a privy and see that the men use same. Keep this place clean by brushing off the seat each day with broom and water. Carefully instruct the men to cover all excretions with ashes, and use lime freely in warm weather. Do not allow the men to urinate around the bunk cars, as this is very insanitary.

3. Have bunk cars screened, and kept free from flies by using swatters and poisons.

4. Ventilate cars by having windows open during day and night, when weather permits.

5. Dispose of garbage daily and keep garbage cans covered at all times. Use lime freely around the cars, and most freely around the garbage can. Keep all dirt and rubbish cleaned up, and have the surroundings free from decaying matter at all times. Refuse should be destroyed by burning.

6. Do not throw trash on the main track side, as this will lead to insanitary conditions along the right of way.

By observing these conditions a healthful, sanitary and wholesome camp will be maintained.

A. E. Campbell,
Health Officer.
G. G. Dowdall,
Chief Surgeon.

Approved:
W. L. Park,
Vice-President and General Manager.

REPORT OF COMMITTEE XIX—ON CONSERVATION OF NATURAL RESOURCES.

R. C. Young, *Chairman;*
R. H. Aishton,
W. K. Barnard,
C. B. Brown,
Moses Burpee,
C. H. Fisk,
E. E. King,
S. N. Williams, *Vice-Chairman;*
C. F. Koppisch,
William McNab,
J. L. Pickles,
J. W. Votey,
W. C. Willard,
Committee.

To the American Railway Engineering Association:

Your Committee on the Conservation of Natural Resources respectfully submits herewith its report to the Nineteenth Annual Convention.

The following subjects were assigned the Committee by the Board of Direction:

1. Continue the study of tree planting and general reforestation.
2. Collect statistics on extent of use of treated timber and of permanent materials to replace untreated timber and bare steel.
3. Report on the conservation and utilization of water power for railway purposes, conferring with Committee on Electricity.
4. Report on the study of coal, fuel-oil, timber, iron and steel resources.
5. Report on the relation of railways to the different conservation projects, reviewing work that has been done by each company up to the present time, and make recommendations on policies economical for railways to follow.
6. Report on measures for the conservation of human life and energy, in order to promote efficiency.

COMMITTEE MEETINGS.

Two meetings of the Committee were held, both at Chicago, one on July 10, 1917, with five members present, and the second on January 29th, with three members present.

PROGRESS REPORTS.

In planning the work for the past year, the Committee considered that it might be desirable to include in its report a digest of the previous reports of the Committee. This would make it easier for the members to note the ground that has been covered and the more important features of the reports that have already been made.

The Committee therefore submits, in Appendix A, a digest of previous reports on the "Conservation of Natural Resources."

In Appendix B the Committee presents a report on the progress being made in Canada on conserving and utilizing the natural resources of the Dominion.

The attention of the Committee has been called to recent developments in saving and using what has heretofore been considered scrap material. Among the notable examples of this comparatively new industry are the plants of the Atchison, Topeka & Santa Fe Railway, located at Corwith, Ill., near Chicago; the plant of the Chicago & Northwestern Railway, located at the West Chicago Shops of that company, and others.

Another feature of economy worthy of mention recently developed is that of repairing frogs and switches by the oxy-acetylene method. It is being successfully used by a number of railroads.

CONCLUSION.

Your Committee recommends that its present report be received as information.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends that subjects (5) and (6) be reassigned for the coming year.

Respectfully submitted,

The Committee on Conservation of Natural Resources.

Appendix A.

DIGEST OF PREVIOUS REPORTS OF THE COMMITTEE ON CONSERVATION OF NATURAL RESOURCES.

Prepared by Dean J. W. Votey.

In preparing the reports in the past, the Committee has been represented at the conventions of the National Conservation Commission and has made use of materials collected and reports issued by other commissions and organizations, including the reports of the Government. It has also had special assistance from railway companies and various corporations. Among the organizations from which material has been secured may be mentioned the following: The Lake States Forest Fire Conference, the Forest Products Laboratory, the U. S. Forest Service, the National Association of State Conservation Commissions, the Western Forestry Conservation Commission, the U. S. Bureau of Mines, the National Forest Conservation Commission and, from Canada, the Commission of Conservation, the Forestry Branch Department of Interior, the Board of Railway Commissioners, the Public Utilities Commission of the Province of Quebec, and the Fuel Testing Division of the Mines Branch, Ottawa.

The ground covered by the Committee's reports has been under the following classification: (1) Timber; (2) Fuel-oil and coal; (3) Iron and steel; (4) Water power. Some attention has also been paid to the conservation of life and limb in the "safety-first" campaigns. The Committee has attempted under these heads to collect and bring together the more recent information in order that the members might see what progress was being made in conservation along these lines.

In addition to the tabulated matter giving the results of experimental investigations or specific information that had been collected, there was published in the report for 1912 a "Bibliography of Articles Pertaining to the Timber Resources of the United States."

Since the Committee was first organized the term "Conservation" has been more clearly defined and the field of conservation much more widely extended. "It now embraces principles of preservation, prevention of waste, the efficient development of every variety of our natural resources and a study of how to make the wealth-producing power, as represented by such features, perpetual by judicious Conservation." "The first principle of Conservation is development, the use of the natural resources now existing in this Continent for the benefit of the people who live here now." "Conservation stands emphatically for development and use of water power now without delay." "The development of our natural resources and the fullest use of them for the present generation is the first duty for this generation." "In the second place, Conservation stands for prevention of waste." "The natural resources must be developed and preserved for the benefit of the many, not merely for the profit of a few." "Conservation demands the application of common sense to the common problems for the common good." It also requires that, in the case of those resources that are replaceable, such steps should be taken as are necessary to restore or renew these resources for the benefit of coming generations.

Conserving natural resources is of special interest to railways in view of the rising prices of all materials produced from these resources that are needed by railways. It is further of interest to these companies insofar as they are depending for business upon industries utilizing these resources. Conservation requires the exercise of the highest economy in the utilization of all of our natural resources.

TIMBER CONSERVATION.

More attention has perhaps been given to the matter of the conservation of timber than of any other of our natural resources, first, because the use of this material in the past has represented a tremendous waste, and second, since timber is one of the natural resources that is replaceable.

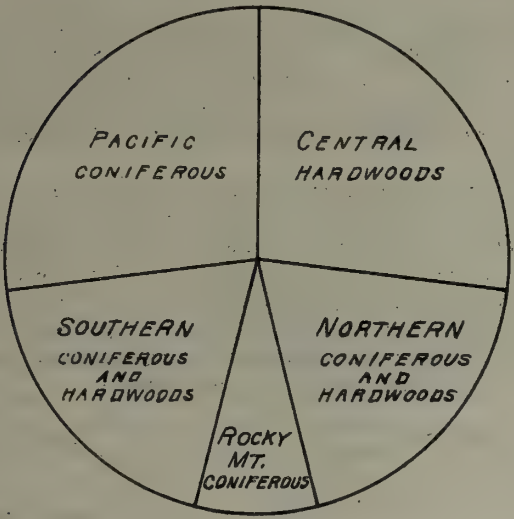
The original forests of the United States were estimated to contain about 5,200 billion ft. B.M. It is estimated that the standing timber in the country at the present time is about 2,800 billion ft. B.M. This is largely concentrated in the Pacific Northwest and the Southern Pine area. About 2,200 billion ft. B.M. is in private hands, while about 600 billion ft. B.M. is in the national forests and in the public lands. We are using 40 cu. ft. of timber per capita annually, while the annual growth of the forests produces only 13 cu. ft. per capita. In certain large forest areas the loss by decay balances the growth. Thirty-five per cent. of standing timber reaches the ultimate consumer, 65 per cent. being wasted in handling. The timber supplies of the country are being depleted through losses by fire, losses by decay in the forests and in the timber as used through wastes in logging and through wastes in sawing and preparing the timber for use.

APPLICATION OF FORESTRY METHODS.

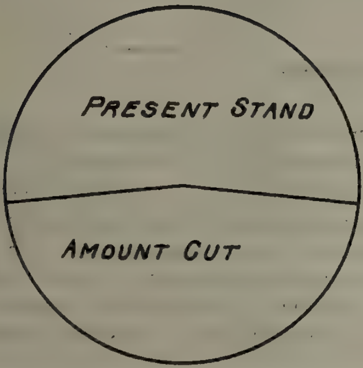
The introduction of proper forestry methods will increase the annual productivity of the forests. A judicious thinning in the forest concentrates the growth on the best trees. The largest results are secured by holding the crop until it reaches mature size. The protection of the young forest growth as well as of mature timber is essential for the future development of the forests. The benefits from forest management are well illustrated by the results secured in certain foreign countries, notably France and Germany.

REFORESTATION OF CUT-OVER AND WASTE LANDS.

A great deal of attention is being given by the interests concerned to the restoration of the forests by the reforestation of lands from which the timber has been cut or of so-called waste land that is unsuitable for agricultural purposes. There is in this country an enormous acreage of such waste land at present producing no revenue.



ORIGINAL FORESTS.



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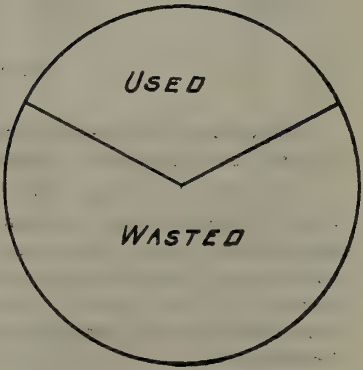
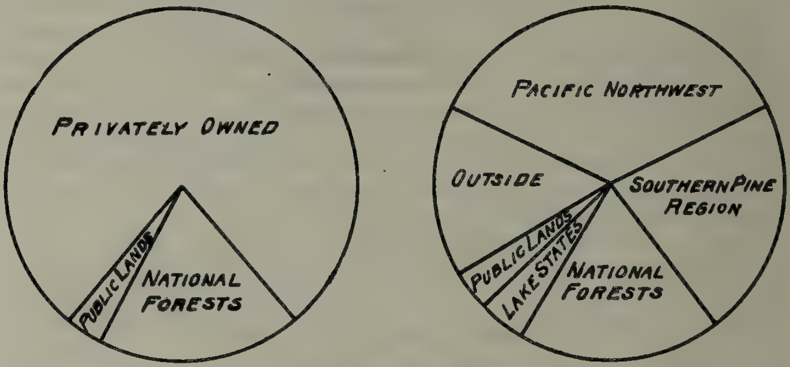


TIMBER LOSS.

Under proper forestry management reforestation will take place in many of these areas in a natural manner where suitable fire protection is afforded.

Several states have adopted the plan of acquiring all cut-over lands that can be had cheaply, in groups as far as possible, as a nucleus of a state forest reserve. The states which are reported as most extensively engaged in reforestation are New York, Pennsylvania, Massachusetts, Vermont, New Hampshire, Connecticut, Ohio, Michigan, Wisconsin and Minnesota.

The Federal Government has also taken part in this movement of reforestation by the purchase of cut-over timber lands, notably in the Appalachian reserve and in the White Mountains; 698,086 acres have been purchased in the White Mountains and smaller tracts have been acquired in the southern Appalachian Mountains. Since 1911 there have been approved for purchase 1,396,367 acres. The Forestry Service of the Department of Agriculture has been reforesting about twenty thousand acres per year in the Western national forests.



Standing Timber.

Many large corporations depending for their raw materials upon the forestry lands are actively engaged in some form of reforestation.

The State of Maine offers a good illustration of this work where there are about a dozen pulp and paper companies owning together more than 2,000,000 acres. The Great Northern Paper Company owns over a million acres from which timber is cut for the manufacture of paper. This company is using modern forestry methods in handling its property. Some details of the company's work is given in Vol. 18, page 603, of the Proceedings.

The importance of the forest industries in Canada has warranted serious attention being given to this matter of reforestation. The main stress there has been placed upon the adoption of protective measures against forest losses from fire.

TIMBER RENEWAL BY TREE PLANTING.

Considerable experimental work is being done by the various states, corporations and individuals in the matter of tree planting on a large scale. This work has been under way too short a time to accurately estimate its value. The work being of an experimental character, it was natural that failure should occur in certain cases. The work of the last few years seems to promise much greater success than the earlier plantings. Experience shows planting forestry stock more successful than seeding and less expensive. The selection of trees for planting have varied with the locality and with the interests concerned. A great deal of white pine has been planted by the northern states. The paper companies have naturally planted spruce suitable for pulp and the railroad companies have selected rapid growing species suitable for ties. As an illustration of the work done in this line by some of the states in 1914, the New York State Conservation Commission furnished some 5,000,000 young trees which were planted on about 5,000 acres divided between the State Forest Reserve, State institutions and private owners.

Attempts have been made by certain railroads to utilize the company's waste land in tree planting for the future tie and timber supply. The Committee in 1915 collected such information as could be secured from these railroads at that time and this data is given in the following tabulation:

TABLE 1—RAILWAY EXPERIMENTS IN TREE PLANTING AS REPORTED IN 1915

Species	Number	Area	Dates	Location	Results
LOUISVILLE & NASHVILLE					
Catalpa	....	700A.	....	Ala.	Failure.
Catalpa	11,000	....	1904–05	Ky.	67.1% lost.
Locust	74,600	....	1904–05	Ky.	65.6% lost.
DELAWARE & HUDSON					
Scotch Pine	1,668,130	1,565.5	1907–15	N. Y.	23% lost.
Scotch Pine	35,900	39	1911–12	Vt.	85% lost.
Red Oak	465,550	450	1911, 13–14	Pa.	10% lost.
Locust	6,600	6	1913	Pa.	10% lost.
Norway Poplar	84,000	84	1913	N. Y.	Failure.
Norway Poplar	194,150	194	1914	N. Y.	15% lost.
Elm	4,900	4	1914	N. Y.	20% lost.
White Ash	19,700	19	1914	N. Y.	20% lost.
CUMBERLAND VALLEY					
Yellow Locust	15,000	200	1906, 1910	....	....
Red Oak	231,600		1908–12	....	....
Yellow Poplar	4,000		1910	....	....
NORFOLK & WESTERN					
Catalpa	2,000	....	1905	Va.	Poor.

TABLE 1—RAILWAY EXPERIMENTS IN TREE PLANTING AS REPORTED IN 1915 (Continued)

Species	Number	Area	Dates	Location	Results
			BOSTON & ALBANY		
Catalpa	....	25	1895 (?)	....	Failure.
			PENNSYLVANIA LINES WEST		
Catalpa	....	51	....	Ind.	Uncertain.
			SANTA FE		
....	....	....	....	Cal.	Growth too slow.
			PENNSYLVANIA		
Black Locust	1,953,214				
Honey Locust	12,673	....	1902–10	....	....
Chestnut	10,316	....	1911–12	....	....
Red Oak	2,405,779	....	1906–09	....	....
Scarlet Oak	800	....	1906–1913	....	....
Pin Oak	30,420	....	1908	....	....
Hardy Catalpa	38,855	....	1907–09	....	....
Black Walnut	16,446	....	1908–12	....	....
Shagbark Hickory	1,752	....	1908–12	....	....
Tulip Poplar	3,120	....	1912	....	....
White Ash	9,609	....	1909, 1913	....	....
Red Gum	2,300	....	1908, '10, '12	....	....
Willow	4,946	....	1910	....	....
Cottonwood	10,340	....	1910	....	....
Norway Maple	120	....	1910	....	....
Sycamore	500	....	1913	....	....
White Pine	30,147	....	1908	....	....
Red Pine	23,145	....	1908–13	....	....
Loblolly Pine	23,839	....	1908, '10, '12	....	....
Western Yellow Pine	560	....	1910–12	....	....
Scotch Pine	441,186	....	1909	....	....
Austrian Pine	2,850	....	1906–13	....	....
American Larch	3,000	....	1912	....	....
European Larch	52,770	....	1907	....	....
Norway Spruce	46,300	....	1907–10, 12	....	....
Douglas Fir	525	....	1908–09	....	....
Northern White Cedar	5,070	....	1908–09	....	....
			1908–09, '13		
			CANADIAN PACIFIC		
Tamarack	25,000	8	1908	....	....
			NEW YORK CENTRAL		
White Pine Scotch Pine Red Pine Larch Red Oak Carolina Poplar	50,000	....	1914	N. Y.	....
			ILLINOIS CENTRAL		
Catalpa	173,000	....	1902	La.	Satisfactory.

Considerable work has been done in some of the Northern states by private individuals who have secured waste land and engaged in tree planting as a business venture. How successful such ventures will prove will depend to a considerable extent upon the protection given to these plantings in the future from losses by fire and other agencies.

Work in tree planting of great value has been done by several of the European nations. In France, immense areas of waste land were recovered by tree planting. Results of very great value have been secured from the timber cut on these lands. France has 2,000,000 acres recuperated at an expenditure of less than $15,000,000 now representing a capital of $135,000,000 from nine times the outlay and an income of ten million dollars annually or 7 per cent. on the valuation. These French forests are of inestimable value in supplying the timber demands for the present war.

PREVENTION OF FIRE LOSS.

"The U. S. Forest Service reports that an average of ten million acres is annually burned over, causing a loss of 25 million dollars. These fires destroy the soil covering in a forest, causing rapid runoff on steep slopes and an erosion and irregularity of stream flow with loss of navigability, hence the necessity of continued state and national co-operation to secure the protection from forest fires which destroy annually twelve million ft. B.M. of timber."

All experiences go to prove that damage by forest fires is practically preventable. Measures for the protection against this loss have been adopted by the U. S. Government in handling its forest reserves, by certain of the states under the Forestry Departments, by some of the railroads whose lines pass through valuable timber lands and by large corporations with valuable timber holdings. The Federal Government co-operates with many states in the fire protection of forests on the watersheds of navigable streams. The combined efforts of these different organizations have resulted in a very large reduction of the annual fire loss. The measures adopted have, in the main, consisted of the establishment of patrol systems for the discovery of fires and fire fighting organizations for dealing with the fires when reported. As many forest fires originate on or near the railroad right-of-way, it has been natural for the railroad to combine with the state and other organizations in providing protective measures for this work. In certain states, this obligation has been placed upon the railway companies by State laws.

"The legislation on fire protection affecting railroads is generally along the lines and requirements for locomotive spark arresters; for devices for preventing the escape of fire from ash-pans and fire-boxes; the prohibition of depositing fire, live coals, etc., on tracks or rights-of-way; the requirements of screening smoking-car windows, cleaning right-of-way, extension of cleaning at dangerous points to strips beyond the right-of-way; maintenance of fire patrolmen to follow trains in forest districts during danger seasons and notification by trainmen of fires observed in passing."

In certain states, notably Michigan, the timber land owners have organized themselves into protective associations and raised the funds to maintain organizations of fire wardens and forest rangers and have co-operated with the state authorities in this matter. The railroads likewise in the timber districts have organized systems of patrol and special fire fighting equipment.

The resolutions relating to forest fire protection adopted at the Lake States Forest Fire Conference in 1910 were reported in full by the Committee, Vol. 12 of the Proceedings. These relate in the main to the slash problem, the railway risk, the maintenance of patrol systems, the building of fire lines around all exposed property and the education of the general public to the hazard involved and the means for its elimination.

In Canada careful attention has been paid to the control of forest fires in order to reduce the enormous loss in that country, by the Board of Railway Commissioners, by the Public Utilities Commission of the Province of Quebec and similar organizations in other Provinces.

The regulations of the Board of Railway Commissioners are quoted in full in the Committee's report in Vol. 14 of the Proceedings. The progress made in Canada under the regulations issued is indicated from the fact that the railways are now considered only a minor source of danger.

Settlers, sportsmen and tramps are reported as being responsible for much of the damage due largely to carelessness. In Canada, as in the States, various protective associations have been organized and have demonstrated the value of co-operative effort in forest fire protection. Two such organizations, the Maurice and Lower Ottawa Forest Protective Associations together protect an area of 16 million acres.

Improved Logging Methods.

Under the methods of logging formerly practiced in this country it has been estimated that one-fourth of the standing timber was left or otherwise lost in logging. Under the improved systems now being adopted this loss is being reduced. The paper mills are able to use wood too small for saw-logs. The hemlock bark is used by the tanneries, while balsam, spruce, poplar and hemlock can be used for paper making. The hardwood may be utilized for by-products. The pine wastes may be utilized in a similar manner. The boxing of longleaf pine for turpentine has been estimated to destroy one-fifth of the forest growth.

Secondary matters in improved logging operations have been the reduction of fire risks in the care of the slash and the better protection of the young growth necessary for reforestation of the area.

Saving Waste in Preparing Timber for Use.

It has been estimated that the loss in the mills in the past has been from one-third to two-thirds of the timber sawed. The loss in the mill product through seasoning and fitting for use has been estimated as from one-seventh to one-fourth. An average of only 320 feet of lumber is used for each thousand feet which stood in the forest. A great reduction in the mill loss is being made by utilizing the mill wastes as a source of supply for by-products or by culling from such wastes material that can be cut and used in smaller dimensions.

The Committee in previous reports carefully investigated the relative use of sawed vs. hewed ties. It was found that about 70 per cent. of the tree was wasted in making hewed ties. A large saving could be made by adopting the sawed tie in place of the hewed. This loss includes not merely the loss of wood in hewing, but also the loss in the logging operations. The Committee's investigations of the tie matter were reported in Vol. 11 of the Proceedings. In this report the relative merits of sawed and hewed ties were stated and the advantages to be derived from the use of the sawed instead of the hewed tie. At that time, the Committee summarized the matter as follows: "Tie hewing cannot be condemned without exception. 1. Hewing is economical for various small trees when these are desirable to cut from the point of growth. 2. Hewing ties from trees under 15 to 18 in. and getting full scales is more desirable for the stumpage owner than being robbed by the scale of most existing log rules, if the price per thousand feet is the same. 3. Hewing ties is desirable in small wood-lots where a mill would be impracticable. 4. Sawing ties is more economical by 20 to 200 per cent. and preferable for trees over 11 in. when the mill man owns the stumpage, or for the independent stumpage owner when he is paid for the full saw output of his logs."

Preservative Treatment of Timber.

The first attempt in this country to prevent decay by treating wood was in 1838 on the North Central Railroad. In 1880 for the first time the U. S. Census undertook to ascertain what remained of our timber resources and it was found they had been very rapidly depleted. The American Society of Civil Engineers then appointed a Committee to find the best methods of preserving wood in order to lengthen its life. That Committee reported in 1885. This was followed by the movement which has culminated in the present large wood preservation industry of the country. The main feature of this work is to lengthen the life of the wood, thereby preserving the forests. A further advantage is that so-called inferior species of timber may be used in the place of the more valuable species, supplies of which are becoming rapidly depleted or the price is so high as to prohibit their use for certain purposes.

In a report on this matter in 1910 it was stated that decay was responsible for the destruction of about 13 per cent. of this product. At that time it was considered that the average life of untreated ties was 7 years, while if properly treated this could be increased to at least 17. It was estimated that if all ties used in renewal were treated, there would be a saving of about 58 per cent. in the consumption on the basis of the mileage at that time. This reduction represented the growth in about

7 million acres of well stocked forest land. The Committee recommended that the railroads adopt the policy of treating and preserving all ties, piles, construction and other timber which are subject to destruction by decay.

UTILIZATION OF BY-PRODUCTS.

Until recent years comparatively little attention has been paid to the utilization of the logging and mill wastes and of the so-called inferior species of timber. This has been especially true in connection with the hardwood where the difficulty of transportation has interfered with the full utilization of this material. In Volume 18, the Committee made a full report on the by-product industry of Michigan and Wisconsin. It was there shown that the hardwood timber was being used in the production of charcoal, wood alcohol, acetate of lime and wood creosote oil. The value of these products for those two states amounted to $9,077 000. As it was estimated that this was 40 per cent. of the total output of the United States the entire saving from wood smoke was considered to be approximately $22,692,500. These industries used as raw material, in the main, the waste products from log timber that was cut into lumber and stock for small wooden articles. Only the rough, knotty logs, limbs or tops were cut into kiln wood.

Chemical plants in southern Michigan were manufacturing much of their product from the slash where in northern Michigan it was cheaper to use the larger wood as a supply of material.

Reference is here made to a report prepared by R. K. Helphenstine, Jr., for the U. S. Forest Service, on the progress of wood preservation for the past eight years. The document may be obtained on application to the Superintendent of Documents, Washington.

Appendix B.

(1) COAL RESOURCES OF CANADA.

William McNab, Chairman, Sub-Committee.

The coal resources and the fuel situation in Canada have been discussed at some length in the previous reports of the Committee of Natural Resources. In this report a brief resume is given of the outstanding features in connection with this industry.

War conditions have brought home to the people of Canada the critical position in which they stand with regard to fuel and the necessity for applying intelligent study to the whole question. In 1916 the total coal production of Canada amounted to nearly 14,500,000 tons, while the imports for the same year exceeded 17,500,000 tons.

Owing to the greater demand for United States coal, incident to her entrance in the present great war on the side of the Allies, it was found necessary to place the sale and distribution of coal in that country under a Fuel Administrator. Owing to the scarcity of coal at lake ports in the spring and to the fact that some 200,000 tons of coal had been lost from production through the "coal strike," the Government of Canada found it necessary to appoint a Fuel Controller and to place the mines of the district, formerly under strike, under a Controller of Mines. As a result of this action, while there may be a shortage at certain points, it is believed that the danger of a coal famine has been averted for this winter at least.

During the year some consideration was given by several departments of the Government to the greater utilization of the lignites of the Prairie Provinces. This work is of great importance and there seems to be little doubt but that a high grade domestic fuel can be made from lignite in the form of carbonized briquettes.

Pulverized Fuel.

The coal reserves of Canada are considerable, but a large proportion is unsuitable for use in the ordinary way as locomotive fuel. The coals of Manitoba, Saskatchewan and portions of Alberta are lignite or sub-bituminous coal, high in moisture, and cannot be used as locomotive fuel on account of the liability of setting out fires from excessive sparking. In 1916, the railways of Canada consumed over 8,675,000 tons of coal and nearly 50,000,000 gallons of fuel-oil, both of which have, during the last few years, steadily increased in price. On account of our large imports of coal and fuel-oil, anything that can be done to increase the efficiency of generating power from coal or to economically curtail the use of fuel-oil by the substitution of Canadian coal or lower grade "sparking" fuels should be investigated and introduced as soon as possible. Coal or lignite burned in the powdered form does not produce sparks, but burns in a similar manner to a gas. During the last few years this class of fuel has been used with success in connection with locomotives, stationary boilers, and various metallurgical industries. It is anticipated that, within a short time, it will be used to a much greater extent in Canada. In this connection, it is of interest to note that one of the large manufacturers of high grade steel in Montreal has recently adopted it in his boilers and heating furnaces.

Canada was the pioneer in successfully using powdered fuel in connection with the smelting of the copper-nickel ores of the Sudbury district.

By-product coke ovens are gradually being introduced in Canada in place of beehive ovens, which waste valuable by-products such as gas, tar and ammonia. There are in the Dominion of Canada at the present time approximately 2600 coke ovens; of these, 910 are by-product ovens producing about 80 per cent. of the coke output. The rest, amounting to about 1700 ovens, convert the coal into coke without saving the by-products. The Granby Consolidated Mining, Smelting & Power Company are installing thirty by-product coke ovens in connection with their smelter at Anyox, British Columbia.

IRON AND STEEL.

Electric Smelting.

About fifteen years ago, the Dominion Government carried on an extensive investigation of the possibilities of electric smelting. When this investigation was made the general opinion prevailed that the time was far distant when electric smelting would be carried into practical operation in Canada. It is, therefore, of interest to note that electric smelting is now in full operation in Canada.

There are, at the present time, 32 Heroult electric furnaces in Canada and 22 of other types—in all 54 furnaces using the electric process. These furnaces have a capacity of 173,000 tons of iron and steel, 50,000 tons of ferro-silicon and 8,000 tons of other ferro-alloys per annum. The British Forgings plant at Toronto has 10 electric furnaces having a total capacity of about 72,000 tons per annum, making it the largest electric process steel plant in the world.

Steel for Shell Making.

An interesting development with respect to steel for shell making has an important bearing on conservation. At the beginning of the war, all shells manufactured in England were made from acid steel. Practically all steel made in Canada was basic steel. Canadian manufacturers had never made shells and it was not certain that they could meet the requirements of the British War Office. At the same time, changing from the manufacture of basic steel to acid steel presented many serious difficulties and would evolve enormous expense. However, Colonel Cantley, Nova Scotia Steel & Coal Company, demonstrated that shrapnel shells that would meet all requirements could be manufactured from basic steel. Later, Canadian manufacturers also demonstrated that high explosive shells that met all tests demanded by the War Office could also be manufactured from basic steel.

At the present time, 250,000 people are employed in connection with the manufacture of munitions; there are 650 plants in 144 cities and towns in Canada, with a total capacity, per annum, of 42,000,000 high explosive and shrapnel shells, varying from 18-pounders to 9.2 inch. This output requires about 1,250,000 tons of steel, 250,000,000 lbs. of brass, 75,000,000 lbs. of copper, 25,000,000 lbs. of zinc, 150,000,000 lbs. of lead and 20,000,000 lbs. of antimony. It also requires 130,000,000 lbs. of explosives—50,000,000 lbs. of cordite, 50,000,000 lbs. of tri-nitro-tuluol. About 170 million feet of board are used in making the boxes for these shipments of shells.

The total value of munition orders to May last was $800,000,000 and the value of munitions shipped was $500,000,000. These munition orders have tremendously stimulated the metal and many other industries, notably the recovery of by-products from the coke oven plants.

It is impossible to properly assess the value to the community of the standardizing of methods and processes and the high degree of skill required to produce a product that is gaged to within one three-thousandth part of an inch and check-gaged to one ten-thousandth part of an inch. Over 250,000 workers have become skilled in such processes and in the use of such tools and gages.

MEMORANDUM ON WATER POWER FOR RAILWAY PURPOSES.

The interests which railways have in water powers may be classed as indirect and direct. The former is probably by far the most important of the two and relates to increase in traffic brought about by the industrial development which water powers have made possible. The direct connection between railways and water powers comes through their electrification by utilizing the latter in the supply of hydro-electric energy.

That main line electrification of railways has not been more extensive in Canada is not due to lack of water power possibilities, but rather owing to the more important factors connected with this question, such as amount of traffic, frequency of service, etc.

Thus far, if we exclude street and suburban lines, railway electrification in Canada has been confined to serve special purposes such as in the Canadian Northern Railway Tunnel, at Montreal; the St. Clair Tunnel of the Grand Trunk Railway, and the Detroit Tunnel of the Michigan Central Railroad.

Several Canadian railways have adopted electricity for suburban and interurban service, particularly near large centers and in southwestern Ontario. At the end of June, 1916, some 32 of these railways were in operation, 85 per cent. of them obtaining their electric energy from water power. If we include the city mileage they represent a total of 1465 miles of single track and a capital of nearly $94,000,000.

While main line electrification on a large scale for purely economic reasons may yet be far remote, we may look forward to a number of possibilities in the near future from the indirect benefits of electric operation. These often are controlling in any installation, and among them may be mentioned smoke elimination in tunnels and underground terminals, overcoming the smoke nuisance on surface lines in large centers, and increased comfort, speed and attractiveness in passenger service. Whatever may be the future of electrification in Canada, and whether conditions warrant it to be effected on a large or small scale, the generously distributed water powers of this country will always be an additional incentive in any project of this character. In many cases hydro-electric power stations will be found already in operation at convenient intervals from which energy could be secured in block without necessitating extra expenses for development. With the exception of that portion of the Prairie Provinces, south of Edmonton between Brandon and Red Deer, water powers for railway electricfication may be found throughout the whole Dominion. In some cases, however, storage conservation may have to be resorted to to provide sufficient energy continuously.

TREE PLANTING AND GENERAL REFORESTATION.

Nowhere in Canada is the reforestation of denuded lands being carried on in more than an experimental or small scale way. Neither the provinces nor the Dominion Government have definitely taken up, on more than the smallest scale, the reforestation of denuded Crown lands. The great bulk of the forest planting that has been done in Canada has been due to the efforts of a few of the more progressive companies, for the most part pulp and paper companies. At least a very large percentage of this planting has been upon Crown granted lands, due to the lack of any definite governmental policy for the encouragement of planting operations on Crown lands by private concerns. Due to the long-time element involved and to the uncertainty of governmental policies, it is to be anticipated that the planting work of private companies will be for the most part confined to privately-owned lands. However, to bring this about on any large scale, it will be necessary for the governments concerned to enact legislation which will prevent the confiscation of the property interests in question through the operation of the general property tax. In a number of the states this matter has received considerable attention, and the effort has been made to encourage forest planting by legislation providing for a fixed moderate taxation during the period required for the plantation to reach maturity, the bulk of the tax being payable when the crop is harvested. The general property tax, as applied to forest properties, has the effect of forcing logging operations, rather than of encouraging the holding of the timber for future use. In the case of a forest plantation, either the whole tax should be deferred for some stated number of years, or else the annual tax should be based upon the value of the land alone, leaving the forest crop to be taxed when it is harvested at the end of the rotation. It is understood that the government of Quebec has under consideration the adoption of special tax legislation calculated to encourage the establishment of forest plantations on non-agricultural lands.

The growing importance of the pulp and paper industries in Canada renders this matter of great economic importance to the country.

For the production of lumber, box boards, etc., white pine has been regarded as one of the most desirable species for planting in eastern Canada. However, the existence of the white pine blister disease in both Ontario and Quebec renders at least doubtful the advisability of planting white pine on any large scale, until more definite information is available as to the possibility of controlling the spread of the pine blister disease. Southern Ontario is already quite heavily infected and the disease has been found in a number of counties in Quebec. Competent authorities consider that it is not feasible, from a practical viewpoint, to eradicate the disease from the districts already heavily infected. It is, however, believed that much may be done to control or retard the spread of the disease to areas where it is not already found, and to minimize its injurious effects where its occurrence is apparently threatening the white pine forests of a given district. The Dominion Government and the Provincial Governments of Ontario and Quebec have this matter in hand.

Planting in Quebec.

The Quebec Forest Service maintains a large nursery at Berthierville, from which a total of approximately 1,500,000 forest tree seedlings have been shipped, mostly to pulp and paper companies. Some experimental plantations have been made by the province in the vicinity of Berthierville, but no definite policy of reforesting Crown lands has been adopted. This is one of the matters which the Government of Quebec should take up vigorously. Some experimental plantations have been made on the sand dunes near Lachute, but this work has, for the most part, been discontinued.

The Laurentide Company, Ltd., has taken the lead in the matter of forest planting. This Company had, up to the end of 1916, planted up a total of 400 acres to spruce and pine, mostly Norway spruce. Their nursery has been considerably extended with a view to a large increase in the planting program. It is anticipated that white spruce will be planted on a large scale. All the land upon which planting has been done or is contemplated by this company is Crown granted land.

A small amount of planting work has been done by the Riordan Pulp and Paper Company, and it is understood that a considerable extension of this work is contemplated.

Some years ago a small plantation was made by the Belgo Canadian Pulp and Paper Company, but this work was not continued. Practically the same is true of the Pejepscot Company.

Planting in Ontario.

The Forestry Branch, Department of Lands, Forests and Mines of Ontario, maintains a forest nursery and planting station in Norfolk County. However, a very large percentage of the plant stock from this nursery is furnished to farmers throughout the province. A number of plantations have been made upon the nursery station but not even a beginning has been made toward the reforestation of denuded Crown lands in general. In a few cases, small plantations have been made with a view to the control of drifting sands, especially where such sands threaten the destruction of highways, cultivable lands or other property.

DOMINION LANDS.

The Dominion Forestry Branch maintains two forest nurseries, at Indian Head and Sutherland, Saskatchewan, respectively. From these nurseries about 4,000,000 seedlings and cuttings are distributed annually to farmers throughout the prairie provinces. The great bulk of the plant material is of hardwood species for windbreaks, shelter belts, etc. Only the smallest beginning has been made toward the reforestation of denuded lands on the Dominion forest reserves. This work is still in the experimental stage, but should be extended to a scale commensurate with the size of the problem involved.

WORK BY THE RAILWAYS.

Considerable work has been done by the Canadian Pacific Railway in the direction of tree planting to replace portable snow fences. This work was first carried on in the prairie provinces, and the results secured are reported as being quite satisfactory. It may be interesting to know that on a section of the Canadian Government Railways—between Campbellton, N. B., and Bathurst, N. B.—there are spruce hedges primarily planted in order to protect the track from snow drifts, and which have in the course of years not only proved effective in that respect, but have appealed to the artistic taste of travelers.

USE OF TREATED TIMBER AND OF PERMANENT MATERIALS TO REPLACE UNTREATED TIMBER AND BARE STEEL.

In the absence of a specific investigation along this line comparatively little information is available. So far as the forestry work is concerned, the question becomes largely one of the use of treated timber. The most interesting aspect of this problem, especially from the railway point of view, is the preservative treatment of cross-ties. It is noted, for example, that while only a relatively small beginning has been made in the preservative treatment of railway ties in Canada, approximately one-third of the ties used by railways in the United States are given preservative treatment. One difficulty in the way of the general use of treated ties by Canadian railways is the fact that there are, so far as known, only five plants in Canada at which railway ties can be given preservative treatment on a commercial scale. These plants are at Vancouver, B. C.; Transcona, Manitoba; Fort Frances and Trenton, Ontario, and Sydney, N. S. It will thus be noted, for example, that for Quebec and the greater portion of Ontario, no tie-treating plants are conveniently accessible. From one-third to nearly one-half of the ties used in Canada are jackpine. The increasing price and decreasing supplies of accessible material of this species suitable for the manufacture of ties, are necessarily bringing about serious consideration of the use of hardwoods, including birch, maple and beech. Of these, there are very large supplies of birch available in the more northerly forests of eastern Canada. Beyond any question, the hardwoods are admirably adapted to use as railway ties providing they are given preservative treatment. This is indicated by the fact that between two and a half and three million ties of beech, birch and maple are now used annually in the United States. The use of these species has increased rapidly, the use of birch being first reported on a material scale in 1915.

In Canada, the use of birch for railway ties is in its infancy. Experience generally appears to indicate clearly that the use of birch ties without preservative treatment is undesirable, since the life of such ties is restricted to four or five years. However, with preservative treatment, the evidence indicates that such ties will have a life of twenty to twenty-five years.

Specific information with respect to this has been secured from the New York Central and Toronto, Hamilton & Buffalo Railways. G. W. Vaughan, Engineer Maintenance of Way of the New York Central Railroad Company, reports that during the past four years the Company has used about 98,000 yellow or red birch ties. All of these have been treated with creosote at a cost of approximately 31 cents per tie. Mr. Vaughan states that he considers the life of birch ties untreated to be four years and treated about 20 years. R. L. Latham, Chief Engineer, Toronto, Hamilton & Buffalo Railway, reports that his Company has been using from 20,000 to 25,000 birch, beech and maple ties per annum during the past three years. Of these, approximately 40 per cent. were birch, mostly yellow birch. All of these ties have been given a treatment of approximately two and a half gallons of creosote per tie. Mr. Latham considers the average life of an untreated tie to be approximately five years and of a creosoted tie from 20 to 25 years. The experience of this company is that beech, birch and maple all take treatment nicely and give splendid service when given the proper creosote treatment.

It is believed that the railway companies in Canada could render a very great service in forest conservation by investigating most carefully the possible use of yellow birch for railway ties and by bringing about, in one way or another, the construction of additional plants for giving preservative treatment to ties and other timbers.

As a matter of general interest, reference is here made to a bulletin entitled "The Substitution of Other Materials for Wood," this being Report No. 117, Office of the Secretary, U. S. Department of Agriculture. The author of this bulletin is Rolf Thelen, Engineer in Forest Products, U. S. Forest Service. In addition to a large amount of other data, this bulletin contains statistics of production, consumption and substitution of other materials for wood in connection with bridges, culverts, trestles, cross-ties, mine timbers, etc.

RELATION OF RAILWAYS TO CONSERVATION PROJECTS.

The relation of the railways to forest planting and wood preservation has been touched upon briefly in the two preceding sections of this memorandum.

Forest fire protection is another conservation problem in which the railways are interested both directly and indirectly. Information received through the Fire Inspection Department of the Railway Commission indicates that on the whole very gratifying progress has been made in the direction of reducing fire losses along railway lines, due to railway agencies. Large areas of cut-over and burned-over non-agricultural lands along railway lines throughout Canada are again growing up to young forest, and it is of great importance that such reproducing areas be saved from further damage by fire. Such a course would add greatly to the attractiveness of the country from a tourist point of view, to say nothing of reducing damage claims and the prospect for future freight traffic when such forests reach maturity. Considering the enormous areas involved, the prospects for future freight traffic from areas now carrying young forest growth are well worth the most careful consideration. Such areas will also serve as a source of supply for cross-ties, poles, posts and other timbers necessary to railway maintenance and operation.

From every point of view, the railways are interested in securing adequate protection of the forests against fires, in the districts through which they operate. Railway officials should accordingly inform themselves with respect to this matter and at every opportunity exert their influence in favor of more adequate methods of forest fire protection, whether by private agencies or governmental organizations.

REPORT OF COMMITTEE XI—ON RECORDS AND ACCOUNTS.

W. A. CHRISTIAN, *Chairman;*
F. L. BEAL,
LESTER BERNSTEIN,
H. BORTIN,
W. S. DANES,
J. W. FOX,
B. B. HARRIS,
GEO. D. HILL,
G. T. KUNTZ,
M. C. BYERS, *Vice-Chairman;*
HENRY LEHN,
J. H. MILBURN,
J. C. PATTERSON,
J. H. REINHOLDT,
R. C. SATTLEY,
HUNTINGTON SMITH,
H. M. STOUT,
W. D. WIGGINS,
Committee.

To the American Railway Engineering Association:

Your Committee on Records and Accounts submits herewith its report to the Nineteenth Annual Convention.

The following subjects were assigned the Committee by the Board of Direction, which were referred to Sub-Committees, as indicated:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.
   J. H. Reinholdt, Chairman; H. M. Stout, Geo. D. Hill.
2. Report on the use of small forms on cardboard or other suitable material for use of fieldmen in making daily reports, to the end that supervision may be facilitated and efficiency encouraged.
   Huntington Smith, Chairman; W. S. Danes, W. A. Christian.
3. Report on feasible and useful sub-divisions of the Interstate Commerce Commission "Classification of Investment in Road and Equipment" and "Classification of Operating Expenses of Steam Roads."
   Henry Lehn, Chairman; M. C. Byers, Lester Bernstein.
4. Report on various methods of reproducing maps and profiles on tracing linen for permanent record.
   W. A. Christian, Chairman.
5. Make a comprehensive study of the problems of recording and reporting the cost of additions and betterments.
   R. C. Sattley, Chairman; W. D. Wiggins, F. L. Beal.
6. Submit specifications for maps and profiles, co-ordinating them with previous work of the Association.
   J. H. Milburn, Chairman; J. C. Patterson, Huntington Smith.
7. Report on valuation forms now in use and recommend forms for both field and office use.
   Geo. D. Hill, Chairman; R. C. Sattley, J. W. Fox.
8. Report on cost-keeping methods and statistical records.
   H. Bortin, Chairman; B. B. Harris, Henry Lehn.
9. Report on a systematic arrangement for final plans in connection with estimates.
   J. C. Patterson, Chairman; J. H. Milburn, B. B. Harris.
10. Report on the allocation of maintenance of way expenses to passenger and freight service.
    Lester Bernstein, Chairman; H. Bortin, M. C. Byers, J. W. Fox.

11. Report on additional definitions.
    W. D. Wiggins, Chairman; W. S. Danes, J. H. Reinholdt.
12. Report on the following forms:
    For Maintenance of Way and Structures:
    (a) Monthly report of Track Tools.
    (b) Monthly report of Roadway Machines.
    (c) Final report of Materials used in Tracks.
    For Construction:
    (a) Monthly estimates of Work done by Contractors.
    (b) Track-laying Reports.
    (c) Track-Ballasting Reports.
    (d) Keeping Material Account.
    (e) Keeping Itemized Cost Record.
    (f) Final Detailed Report and Record.
    For Records:
    (a) Building Record.
    (b) Water Service Record.
    (c) Fuel Station Record.
    (d) Shop Machinery and Tool Record.
    H. M. Stout, Chairman; G. T. Kuntz, F. L. Beal.

COMMITTEE MEETINGS.

The General Committee has held no meetings during the year, owing to the prevailing conditions, but the work has been carried on by correspondence. Meetings of the several Sub-Committees have been held at various times and places.

(1) REVISION OF THE MANUAL.

The Committee has no specific recommendations to make for changes in the Manual, but submits, in Appendix A, a brief discussion on standardization of forms and stationery, and also suggests that consideration be given to reducing the number of forms and reports in the Maintenance of Way Department.

(2) THE USE OF SMALL FORMS ON CARDBOARD OR OTHER SUITABLE MATERIAL BY FIELDMEN.

This subject is under consideration by the Sub-Committee, but the study has not progressed sufficiently to make a report at this time.

(3) SUB-DIVISIONS OF I. C. C. CLASSIFICATION OF INVESTMENT IN ROAD AND EQUIPMENT.

In the report submitted in 1917 the Committee presented a discussion of desirable changes in the Sub-Divisions of the I. C. C. Road and Equipment Classification, which was received as information. The Committee reports progress on this subject for the present, and suggests that it be reassigned for the current year.

(4) METHODS OF REPRODUCING MAPS AND PROFILES ON TRACING LINEN FOR PERMANENT RECORD.

In its report for 1916 (see Proceedings, Vol. 17, pp. 419, 420) the Committee presented such data as it had been able to accumulate on this subject. There have been no new developments in this matter, as far as the Committee has been able to ascertain, since that report was submitted, and we have therefore no report to present. It is further suggested that this subject be discontinued.

(5) RECORDING AND REPORTING COST OF ADDITIONS AND BETTERMENTS.

In Vol. 18, Proceedings for 1917, the Committee presented four tentative forms for the use of railroad companies under Federal valuation for reporting addition and betterment work. These four tentative forms were received as information at the last annual convention. The Committee has no further report to make on this subject at the present time.

(6) SPECIFICATIONS FOR MAPS AND PROFILES.

On pp. 759-768 of Vol. 18, Proceedings for 1917, the Committee submitted Specifications for Maps and Profiles, which were received as information at the last annual convention.

These specifications have now been before the members for one year, but no comments or criticism has been received by the Committee during the year. The Committee therefore submits the Specifications for Maps and Profiles, as shown on pp. 759-768 of the Proceedings for 1917 for approval and publication in the Manual. In the interest of economy in printing, the matter is not reprinted here, but reference is given to the specifications, as above.

(7) VALUATION FORMS FOR BOTH FIELD AND OFFICE USE.

In response to a circular addressed to Valuation Engineers of railroads represented in the Association, the Committee obtained a large amount of most valuable information. This data has been carefully studied by the Committee, and after due consideration it has been decided not to recommend any additional valuation forms at this time. One reason for this conclusion is that the subject was quite fully covered in the last annual report of the Committee (see Vol. 18, Proceedings for 1917), consisting of a large number of typical valuation forms; an additional reason is the difficulty of devising forms to cover the great variation of local conditions existing in different sections of the country.

It is therefore the suggestion of the Committee that the various forms collected by it be placed on file in the office of the Association for the inspection and use of anyone interested.

The Committee desires to place on record its appreciation of the generous responses to its request for informaeion.

(8) COST-KEEPING METHODS AND STATISTICAL RECORDS.

The Committee during the past year has given considerable time and study to this topic, but is not prepared to present a definite report at the present time.

All the known available sources of information have been consulted, but it has been found that there is a dearth of suitable data on which to base a conclusive report.

The Committee has been impressed with the widespread interest manifested in this subject, and suggests that it be reassigned for further study.

(9) SYSTEMATIC ARRANGEMENT FOR FINAL PLANS IN CONNECTION WITH ESTIMATES.

On this subject the Committee reports progress and requests that it be reassigned.

(10) ALLOCATION OF MAINTENANCE OF WAY EXPENSES TO PASSENGER AND FREIGHT.

The Committee has made some progress on this subject, its activities having been confined to collecting a list of references to published data and digesting the great amount of matter that has appeared on this topic.

Progress is therefore reported for the present, with the request that the subject be reassigned.

(11) ADDITIONAL DEFINITIONS.

The Committee has interpreted this subject to mean definitions covering valuation matters, and in accordance with that understanding it is preparing a series of definitions pertaining to valuation of railroads, but it not prepared to submit them with this report, preferring to give more consideration to the proposed glossary of terms. It is therefore the request of the Committee that this subject be again assigned to it for the coming year.

(12) VARIOUS MAINTENANCE OF WAY DEPARTMENT FORMS.

The Committee has gathered some data to aid it in making a report on this subject, but owing to the unusual conditions prevailing during the past year, it has not been feasible to make a report. The information collected is being made use of in studying the matter, and it is hoped to present something to the Association at its next annual meeting that will be of value. In the meantime we ask that it be again referred to us for the current year.

CONCLUSIONS.

1. Your Committee recommends that the "'Specifications for Maps and Profiles," shown on pp. 759-768 of Vol. 18, Proceedings for 1917, be adopted and published in the Manual.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends that all subjects assigned it last year, with the exception of No. 4, be again referred to it for the current year.

Respectfully submitted,

THE COMMITTEE ON RECORDS AND ACCOUNTS.

Appendix A.

(1) REVISION OF MANUAL.

The subject-matter in the Manual under the head of Records and Accounts has been carefully considered by the Committee during the past year, but no specific changes are recommended at this time.

The Committee desires, however, to call attention to the desirability of reducing the number of forms used in the Maintenance of Way Department in the interest of economy and efficiency. As an illustration may be cited the experience of an official of a large railway system, who, after making a careful analysis of the different blank forms used in the several departments, reduced the number from 1500 to 500. This large decrease not only involved a great saving to the railroad company in clerk hire and for stenographers, but it also relieved the different officials from the unnecessary labor of examining and considering the mass of details from which no adequate results would be obtained.

Another feature to which the Committee would call attention is the need for standardizing the sizes of forms, stationery, specifications, drawings, etc. There is no good reason why one railroad should use a letterhead of an odd size, like 8 by 10 inches, or one of 7¾ by 12 inches, or other odd dimensions. The standard size letterhead is 8½ by 11 inches, which cuts from a sheet 17 by 22 inches without waste. Anything differing from that size is considered a "special," and consequently costs more money.

Specifications are also made of all sizes for no apparent reason except precedent. If specifications were uniformly written or printed on standard size sheets, it would effect a material saving and would fit in any ordinary letter file. The same argument applies to all sorts of drawings, which it would be an advantage to produce on letterhead-size sheets. The use of large sheets for drawings, except in special cases, has been discontinued in many engineering offices, the drafting now being done on letter-size paper. Instead of tracing cloth, cross-ruled thin paper from which blueprints can be made is recommended.

REPORT OF COMMITTEE XIII—ON WATER SERVICE.

A. F. Dorley, *Chairman;*	J. L. Campbell, *Vice-Chairman;*
J. T. Andrews,	W. C. Harvey,
C. A. Ashbaugh,	C. R. Knowles,
R. C. Bardwell,	E. G. Lane,
F. T. Beckett,	J. D. Mathews,
E. H. Brown,	W. A. Murray,
C. Bucholtz,	E. H. Olsen,
C. C. Cook,	W. A. Parker,
R. H. Gaines,	H. N. Rodenbaugh,
E. M. Grime,	*Committee.*

To the American Railway Engineering Association:

Your Committee on Water Service presents below its report to the Nineteenth Annual Convention.

The Committee was instructed by the Board of Direction to make a study and report during the year on the following subjects:

(1) Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

(2) Continue the study of methods for complying with Federal regulations in regard to purity of drinking water supplied to trains.

(3) Make final report on design of impounding reservoirs, and conditions under which they are economical.

(4) Make final report on relative merits of continuous and intermittent water softeners.

(5) Make final report on rules or examination questions for care of boilers in pumping stations.

(6) Report on organization for railway water service department.

(7) Report on definitions of terms used in railway water service.

(8) Report on suitable types of water meters for use in railway water service, methods followed in testing and reading meters, and checking the consumption of city water.

COMMITTEE MEETINGS.

In addition to various meetings of Sub-Committees, two meetings of the General Committee were held in the office of the Association at Chicago, and one meeting at St. Louis.

SUB-COMMITTEES.

The following Sub-Committees were appointed to make the necessary investigations and prepare reports on the several subjects assigned, the number of the Sub-Committee in each case being the same as the number of the subject in its charge:

Subject (1) J. L. Campbell, Chairman; C. R. Knowles, R. H. Gaines.

Subject (2) R. C. Bardwell.

Subject (3) E. H. Olsen, Chairman; A. F. Dorley, F. T. Beckett, C. A. Ashbaugh, J. D. Mathews, W. A. Parker.

Subject (4) R. C. Bardwell, Chairman; C. R. Knowles, A. F. Dorley.

Subject (5) W. C. Harvey, Chairman; C. R. Knowles, E. M. Grime.

Subject (6) C. R. Knowles, Chairman; E. H. Brown, G. Bucholtz.

Subject (7) C. R. Knowles, Chairman; J. L. Campbell, R. C. Bardwell.

Subject (8) E. G. Lane, Chairman; J. T. Andrews, C. C. Cook, H. N. Rodenbaugh, W. A. Murray.

(1) REVISION OF MANUAL.

Changes in the Manual under the heading of "Water Service" in the 1915 edition of the Manual are recommended in Appendix A.

(2) METHODS FOR COMPLYING WITH FEDERAL REGULATIONS IN REGARD TO DRINKING WATER SUPPLIED TO TRAINS.

A progress report on this subject appears in Appendix B.

(3) DESIGN OF IMPOUNDING RESERVOIRS.

A large amount of information has been gathered by the Sub-Committee having this subject in hand, but it was found impossible to complete the report in time for presentation to this convention.

The subject is an important one on many roads, particularly those in the West, and the Committee hopes, during the coming year, to complete a report on this topic, with definite conclusions and recommendations.

(4) RELATIVE MERITS OF CONTINUOUS AND INTERMITTENT WATER SOFTENERS.

A report on this subject appears in Appendix C, and is submitted as information.

(5) RULES OR EXAMINATION QUESTIONS FOR CARE OF BOILERS IN PUMPING STATIONS.

This subject is dealt with in Appendix D, and is submitted for adoption and publication in the Manual.

(6) ORGANIZATION FOR RAILWAY WATER SERVICE DEPARTMENTS.

A report on this subject is made in Appendix E, and is submitted as information.

(7) DEFINITIONS OF TERMS.

Definitions of terms used in railway water service are submitted in Appendix F for adoption and publication in the Manual.

(8) SUITABLE TYPES OF WATER METERS FOR USE IN RAILWAY WATER SERVICE.

Some study of this subject has been made by the Committee, but the report is not in shape for presentation to this convention, and the Committee suggests that this subject be reassigned for study during the coming year and for report to the next convention.

POLLUTION OF WELLS FROM OVERLYING OR ADJACENT CINDER DEPOSITS.

As a matter of interesting information, the Committee presents in Appendix G a communication from Mr. W. C. Curd, Contracting Engineer, of the Layne & Bowler Company, Memphis, Tenn., on the subject of pollution of wells from overlying or adjacent cinder deposits.

The Committee did not have an opportunity to make further investigation, as suggested by Mr. Curd, but will do so, if agreeable to the Board of Direction. The data submitted by Mr. Curd is presented as useful information.

CONCLUSIONS.

Your Committee on Water Service requests the following action on its report:

1. That the changes in the subject-matter on Water Service under the heading, "Revision of Manual," be adopted and substituted for the matter now given in the Manual.
2. That the report on methods for complying with Federal Regulations in regard to purity of drinking water supplied to trains be received as information.
3. That the subject of the design of impounding reservoirs be reassigned to the Committee for completion during the coming year.
4. That the report on relative merits of continuous and intermittent water softeners be received as information.
5. That the report on rules and examination questions for care of pumping stations be adopted by the Association and inserted in the Manual.
6. That the report on organization for railway water service departments be received as information.
7. That the definitions of terms given in the report on Subject No. 7 be adopted by the Association and inserted in the Manual.
8. That the Subject No. 8, on suitable types for water meters for use in rail water service, be reassigned to the Committee for study and completion during the coming year.

SUGGESTED SUBJECTS FOR NEXT YEAR'S STUDY AND REPORT.

1. Make final report on design of impounding reservoirs and conditions under which they are economical.

2. Make final report on suitable types of water meters for use in railway water service, methods followed in testing and reading meters, and checking the consumption of city water.

3. Continue the study of methods for complying with Federal regulations in regard to purity of drinking water supplied to the public and employes on interstate trains.

4. Submit plans and recommendations for typical water station layouts.

5. Make a study of prevalent locomotive flue failures alleged to be due to improper water conditions and suggest remedies.

6. Revision of the Manual.

Respectfully submitted,

THE COMMITTEE ON WATER SERVICE.

Appendix A.

(1) REVISION OF MANUAL.

J. L. Campbell, Chairman, Sub-Committee.

The following changes in the subject-matter on Water Service appearing in the 1915 edition of the Manual are recommended to the Association:

Page 443.

Article 1.

Manual.—In locating water stations along a railway, an investigation should be made of all the available water supplies, and care should be taken to avoid the use of poor water, or to curtail its use as much as possible.

Suggested revision.—Location of water stations and quality of water being factors affecting operating efficiency, investigation of available supplies should be made, securing as nearly as practicable favorable locations and elimination of water of inferior quality.

Article 2.

Manual.—Most water used in locomotive boilers contains scale-forming matter in solution or suspension, causing trouble and expense in the operation and maintenance of locomotives.

Suggested revision.—Water usually contains scale forming matters in solution or suspension causing trouble and expense in operation and maintenance of locomotives.

Article 3.

Manual.—Hard water can be softened before it is put into locomotive boilers by treatment with chemicals.

Suggested revision.—Hard water can be softened by treatment with chemicals.

Article 4.

Manual.—The hardness of water due to carbonates of lime and magnesia can be removed at a moderate expense for chemicals by the use of lime alone, without adding any soluble salts to the softened water.

Suggested revision.—The hardness of water due to carbonates of lime and magnesia can be removed by use of lime, a comparatively inexpensive chemical.

Article 5.

Manual.—The hardness of water due to sulphates of lime and magnesia can be removed by the use of soda ash, a more expensive chemical. The chemical reaction removes sulphates of lime and magnesia, and leaves soluble sulphates of soda, which increases the tendency to foam.

Suggested revision.—The hardness of water due to sulphates of lime and magnesia can be removed by use of soda ash, a more expensive chemical. The chemical reaction leaves soluble sulphates of soda, increasing the tendency to foam.

Article 6.

Manual.—The removal of sulphates of lime and magnesia is of greater moment than the removal of the carbonates alone, as the carbonates of lime and magnesia, without the presence of the sulphates of lime or magnesia, do not form hard scales, but are precipitated in the boiler as soft scale and mud.

Suggested revision.—The removal of sulphates is more important than removal of carbonates; the latter in absence of the former being precipitated in the boiler without forming hard scale.

Article 8.

Manual.—At stations where hard water is used, special study should be made relative to the economical value of treating the water, and the method best adapted to meet the conditions.

Suggested revision.—When use of hard water is necessary or desirable, study to determine the best method and the economical value of treating it should be made.

Article 9.

Manual.—The cost of installing a water-softening plant varies according to the capacity of the plant, its type, cost of material and labor in the particular locality, and other local conditions.

Suggested revision.—The cost of installing a water-softening plant is affected by its capacity, prices of material and labor and locality.

Page 444.

Article 10.

Manual.—The cost of operating a water-softening plant varies according to the efficiency of the water-softening apparatus and the cost of lime and soda ash, or other chemicals available for softening water in the particular locality.

Suggested revision.—The cost of operating such a plant is affected by the efficiency of its apparatus and the cost and efficiency of chemicals, labor and supervision.

Article 11.

Manual.—The amount of chemicals required to soften water varies according to the quantity of hardening matter in the water, and also its composition.

Suggested revision.—The kind and quality of chemicals required are affected by the quality and quantity of impurities in the water.

ARTICLE 13.

Manual.—The greatest disadvantage in treating water is the increased tendency to foam, due to the reaction of soda ash on the sulphates of lime and magnesia.

It is recommended that this article be omitted.

ARTICLE 1.

Manual.—Special study should be made relative to the economical value of treating the water, and the method best adapted to meet the conditions.

Suggested revision.—Study should be made to determine the best method and the economical value of treating the water, controlling conditions considered.

Page 445.

ARTICLE 1.

Manual.—Adequate supervision is necessary to successful operation of a softening plant. Such supervision should be exercised at least in part by a chemist or an Engineer having adequate knowledge of water treatment.

Suggested revision.—Adequate and capable supervision, preferably by a chemist or engineer experienced and skilled in water treatment, is necessary to secure the best results.

ARTICLE 2.

Manual.—Provision should be made for frequent analyses or hardness tests of both treated and raw water. This is necessary, principally as a check on the treatment, and also on account of changes in the condition of the raw water.

In order that the analyses shall be effective, they must be made under the supervision of a competent chemist.

Suggested revision.—As a check on the treatment and to keep it properly adjusted to changes in the quality of the untreated water, frequent analyses of the water, treated and untreated, should be made by a competent chemist.

ARTICLE 3.

Manual.—Where consumption of water is in excess of the rated capacity of the plant, the use of undertreated, milky water should be avoided by the use of raw water to such an extent as to give ample time for the proper treatment of all water that passes through the softener. The exception to this rule is the case of water which is being treated for corrosive properties. Such water should not be used raw if it can be avoided.

Suggested revision.—When consumption of water is in excess of the effective capacity of the plant, the excess should be used untreated rather than to have all the water imperfectly treated, except water being treated to eliminate corrosive properties only, all of such water preferably receiving a degree of treatment.

Page 448.

Manual.—Table 1 is developed from these equations and gives the proper settling capacity per 1000 gallons per hour capacity of treating plant under various conditions and varying number of settling tanks. From this table it will be noted that with the same time allowed for reaction and precipitation, the least number and the smallest capacity of settling tanks is required where the flow of the untreated water to the softener is double the hourly capacity of the softener, and the one pump works alternately filling and emptying these tanks. Where pumping is a necessity and sufficient supply can be obtained, the one-pump plan will be the most economical in maintenance and operation of the intermittent plants.

Suggested revision.—The foregoing equations give the results tabulated in Table 1, showing the proper settling capacity per thousand gallons per hourly capacity of treating plant under the conditions stated therein. Allowing equal time for reaction and for precipitation, the least number and the smallest capacity of settling tanks are required when the rate of flow of untreated water to the softener is twice the hourly capacity rate of the softener and the pump works alternately filling and emptying the tanks. The one-pump plan, when practicable, will be the more economical in maintenance and operation of intermittent plants.

Page 450.

Foaming and Priming.

Manual.—Foaming from treated water is due to the presence of sodium salts, as a result of treatment for incrusting sulphates, together with such quantities of the alkali salts which may have been present in the raw water. This condition is aggravated and to a large extent due to the presence of suspended matter in the water.

Concentration of foaming solids in locomotive boilers reaches the critical point at about 100 grains per gallon. Concentration above this point must be avoided by changing the water, or else trouble from foaming will be experienced.

The grains per gallon of foaming matter in solution represent the minimum per cent. of water which must be wasted in locomotive boilers to keep the concentration at the critical limit.

In other words, for each pound of foaming matter per 1000 gallons of water, the expense would be equal to the cost of pumping and treating at least 70 gallons of water, and the fuel for heating the same to the temperature of boiling water.

Aside from occasional complete change of water at terminals, partial changes are made by blowing-off of boilers either at terminals or on the road.

Suggested revision.—Foaming of treated water is caused by the presence of sodium salts resulting from treatment to eliminate incrusting sulphates and by the presence of alkali salts and matter in suspension in the water.

Concentration of foaming solids in locomotive boilers reaches the critical point between 100 and 200 grains per gallon, depending upon the character of the foaming solids and the amount of suspended matter in the water. To prevent foaming, the concentration must be kept below that point.

The grains per gallon of foaming matter in solution represent the minimum percentage of water which must be wasted from locomotive boilers to keep the concentration at the critical point.

The cost of so maintaining the concentration equals the cost of pumping, treating and heating to the temperature of boiling water not less than 70 gallons of water for each pound of foaming matter per thousand gallons of water.

Page 451.

FOAMING AND PRIMING (Continued).

Manual.—The most efficient results are obtained by systematic, frequent blowing-off of the boilers on the road, as well as at terminals, together with occasional complete blowing-down and washing of boilers.

There are, of course, conditions where concentration of foaming solids is so great that the required amount of blowing-off would be both impracticable and uneconomical, and it is necessary to resort to anti-foaming compounds.

Suggested revision.—The best results are obtained by systematically frequent blowing-off of the boiler while the locomotive is running and occasional complete blowing-down and washing the boiler at terminals.

When unavoidable concentration of foaming solids is so great that the required amount of blowing-off is impracticable or uneconomical, it is necessary to use anti-foaming compounds.

Page 453.

SUPPLY—SOURCE.

Manual.—Dug well construction should always be preceded by a careful auger test to determine the strata to be encountered. Size and construction depend on the strata to be passed through; no definite rule can be given.

Surface pipe wells are satisfactory where local conditions permit of their use. This system is one which can be extended to collect a large volume of ground water. The recommended layout is shown in Fig. 1.

Artesian deep wells, where obtainable, are a satisfactory source; however, their flow is liable to constant decrease and finally cease.

Deep wells requiring pumping are recommended only as a last resort. The recommended form for record is shown on M. W. 1304.

A chemical analysis should be made of all water, and the question of cost of treatment, if required, thoroughly investigated, as outlined under the heading "Minimum Quantity of Scaling and Corrosive Matter which will justify Treatment."

Suggested revision.—In unproved ground, dug well construction should be preceded by test borings to reveal the strata to be penetrated. The character of the strata largely determines the size of the well and the kind of construction necessary.

The pipe system of driven or drilled wells shown in Figure 2 being capable of wide extension, is satisfactory for underground water when found at shallow depths easily reached by the system.

Permanent artesian wells are a satisfactory source of water supply.

Deep wells, usually costing more for maintenance and operation than other sources, are generally, for that reason, very undesirable, but their disadvantages are sometimes compensated by the excellence and security from pollution of the water yielded by them.

Chemical analysis should be made of water from actual and prospective sources and the cost of treatment, if required, determined as hereinbefore indicated and outlined.

Appendix B.

(2) METHODS FOR COMPLYING WITH FEDERAL REGULATIONS IN REGARD TO PURITY OF DRINKING WATER SUPPLIED TO TRAINS.

R. C. BARDWELL, Chairman, Sub-Committee.

The progress of the regulations in regard to drinking water used on railway trains under the supervision of the Public Health Service, has been largely retarded during the past year on account of the great amount of important work necessitated by the establishment of the cantonment camps and the small force assigned to handle these duties.

The Public Health Department now has seven cars fitted as traveling laboratories for checking the quality of water supplies, but these of late have been used mostly for military purposes. The establishment of additional headquarters for the various sanitary districts has also been delayed on account of men trained in this work being now engaged in army work.

The principal steps in advancement were the adoption of new standard methods of analysis, and an amendment to the regulations pertaining to drinking water supplies require a certificate showing not only that the water conforms to the bacteriological standards as outlined in last year's report, but also that it is from a supply which is not exposed to contamination. This enlarges the scope of the regulations and assures a greater probability of a suitable water being furnished than could be expected under a semi-annual bacteriological test alone. The sanitary survey governs features which in a great measure are susceptible to correction and control.

It is contemplated by the Public Health Department to call a conference in the near future of the State Health authorities for the purpose of standardizing water inspections as well as to define the requirements in source and method of supply. If it is the pleasure of this Association, your Committee will be pleased to report on the engineering and maintenance matters of interest brought out at this meeting.

Appendix C.

(4) RELATIVE MERITS OF CONTINUOUS AND INTERMITTENT WATER SOFTENERS.

R. C. BARDWELL, Chairman, Sub-Committee.

This subject was first brought to the attention of the Association by this Committee in 1907, in the discussion of the relative economy of Continuous and Intermittent Softeners. In bringing the respective advantages of these two systems before you at this time, properly designed plants of both types are assumed.

When Dr. Clark first applied chemistry to water softening in 1841, by adding slacked lime to water for the purpose of removing the carbonate hardness, and later Dr. Porter used soda ash for the removal of the injurious sulphate incrustants, the method was practically the same as in the intermittent plant of to-day. In the modern plant only those refinements have been introduced as were made necessary by the requirement of handling much larger quantities of water. In the intermittent system, which is also known as "Batch" treatment, a definitely known quantity of water is pumped to the tank and the necessary chemicals for its treatment are added. After proper agitation and time allowance for settling of the precipitate or sludge, the water is in satisfactory condition for use in locomotive boilers.

The continuous plant, in which a definite ratio of chemical solution is added simultaneously with the flow of water to the tanks, was a development first considered in Europe and later given attention in this country. During the past twenty years, several good plants of this type have been developed and placed on the market in the United States. This type readily lends itself to numerous mechanical adaptations, and several of these have been largely exploited and are generally known.

A survey of the field indicates that there are now in service on American railroads, approximately 550 water-softening plants, at which about 30,000,000,000 gallons of water are softened annually. In addition to this a large amount of water is partially treated in roadside tanks with soda ash alone, with no allowance for sedimentation. The total amount of water consumed annually for steam purposes by these railroads is approximately about 450,000,000,000 gallons; or nearly 6.7 per cent. of the total water used for steam purposes is completely treated. The continuous type of plant seems to predominate, about 70 per cent. of the total number of plants installed being of that character.

As to the comparative economy of Continuous and Intermittent plants, the operating costs seem to be very nearly the same in well-designed plants of both types. The amounts of chemicals required should be the same in either type, although improper design in the agitating facilities of some types has been found to allow a part of the lime reagent to settle into the sludge before reaction has taken place. Investigation as to running repairs required indicates that these are so largely influenced by the design and location of the plant and the daily attention given to its operation that no general comparison of the two types can be made on this basis. The labor cost generally should also be the same, as with any type of treating plant in railroad service, the constant attention of a man is highly desirable and decidedly economical. There seems to be little difference in the fuel or power item, although conditions vary in different localities. The large variety of type of the many plants installed precludes a general comparison as to interest and depreciation.

The following are the general advantages of the two types:

INTERMITTENT.

1. The most advantageous arrangement for Intermittent plant consists of two settling tanks, road tank height, to serve alternately as treating and settling tanks. This arrangement provides duplicate tank facilities and increased ratio storage capacity to daily consumption.
2. The Intermittent plant is of the most simple construction and its operation is readily understood by the low paid class of service usually engaged for this work.
3. The cost of maintenance of the type of intermittent plants generally in use is small, the necessary repairs simple, and the materials for making them readily available.
4. The uniformity of treatment is certain, large amounts of water being treated at a time, and the opportunity for error is slight.
5. The intermittent plant has no intricate or expensive parts to deteriorate, as are frequently present in some continuous types.
6. A portion of the old sludge remains in the tank and is mixed with the water on each addition of reagents. This acts as a foundation for the newly formed molecules of sludge, causing precipitation in larger particles, and thereby hastening the settling.

CONTINUOUS TYPE.

1. In large plants, the continuous type can be designed to afford more economy in ground space.
2. It will handle a larger volume of consumption on a smaller rate of flow, since the action is continuous and there is no dead time for settling.
3. Where pump station is located at some distance from delivery tank, some types of continuous plants adjacent to the point of delivery are advantageous.
4. At terminals, or where proper attention can be given to the plant at stated periods, attendance at continuous plants can be performed more readily by employes engaged primarily in other duties, but this brings uncertain results due to divided responsibility, and is, therefore, of doubtful advantage.

5. In a certain type of continuous plant, very thorough and gradual mixing is secured by introducing the water and reagents at the bottom of the mixing tank and keeping a portion of the old sludge continually agitated with the incoming mixture, thereby aiding reaction and sedimentation.

Appendix D.

(5) RULES OR EXAMINATION QUESTIONS FOR CARE OF BOILERS IN PUMPING STATIONS.

W. C. HARVEY, Chairman, Sub-Committee.

INSTRUCTIONS FOR CARE OF WATER STATIONS.

Duties of Attendant.

The Pumper, Station Agent or other person in charge of the local water supply will be held responsible for the condition of the entire plant. His first duty will be to see that there is an ample supply of water available for locomotive use at all times.

In case of trouble that affects the water supply he must wire the Chief Dispatcher as well as the Water Service Foreman, stating fully the trouble and what is needed for repairs. He must make frequent inspection of all parts of the plant and make all repairs within his power and avoid sending for repair man except when absolutely necessary. He will be responsible for the safe-keeping and economical use of supplies furnished to the water station and place orders for fuel and supplies in ample time to avoid a shut-down of the plant.

Pumphouse.

The attendant must keep pumphouse neat and clean and take every precaution against loss or damage by fire. Waste or other combustible material must not be stored in the pumphouse. Oil and gasoline must be stored outside in proper receptacles. Cinders must not be dumped close enough to the house to endanger it. Proper place must be provided for all tools and they must be returned to their proper place after using.

Machinery.

Machinery must be inspected daily and adjustments made to increase efficiency and to prevent wear or breakdown. Particular attention must be given to the packing and lubrication of all parts. Attendant must be familiar with the location and purpose of all steam and water pipes, valves, levers, etc., so that in case of accident or leaks the valves controlling same may be properly used.

When ordering repair parts for any piece of machinery attendant must always give the name of manufacturer, shop number of the machine and repair number of the part wanted.

Boilers.

Attendant must see that the boiler contains a sufficient amount of water before starting a fire and shall see that the gage-cocks, water glasses and safety valves are clean and in good condition.

Fire must be frequently cleaned of clinkers. Ashes must not be allowed to accumulate beneath the grate. If muddy water is used, boilers must be blown down frequently. In doing this, boiler must be filled full of water and blown down to one gage with not over 30 lbs. of steam. Foaming is due to a dirty boiler and can be stopped by blowing down and filling with fresh water. Boiler must be washed out once a week or oftener if in the judgment of the Water Service Foreman it is necessary. Flues must be frequently cleaned of ashes and soot.

If it develops, when plant is operating, that no water appears in the water glass the valve below water column should be opened. If water then appears, the flow to the boiler can be increased; if not, fire must be pulled and boiler cooled before turning any water into the boiler. Where more than one shift is in charge of the pumping plant each oncoming man should be notified, by the man leaving, of any defects.

Should safety valve stick and steam gage show over-pressure, draft doors should be closed and boiler allowed to cool off to pressure at which valve is supposed to work before any repairs or adjustments of the safety valve is attempted.

Oil Engines.

Attendant must be provided with a copy of and must be governed by the manufacturer's printed instructions for operating the particular type of engine in his charge.

To secure economical and satisfactory operation, engines must be properly lubricated. Attendant must see that all moving parts are free from dirt, properly oiled and work easily. Lubricating oil must be fluid enough to be fed readily through the oiler. When oiler is filled the lubricating oil should be run through a fine mesh strainer inserted in a funnel. The cover of the oiler should be in place at all times except when filling it. The oiler should be drained occasionally and washed out with gasoline. This applies also to the bearing oil cups.

The machinery to be driven should be detached from the engine until engine is in motion.

Before starting see that tank contains fuel and that a supply of cooling water is available. Thermometers are frequently provided which show the temperature of the cooling water around the cylinder. When running the thermometer should register 140 to 180 degrees Fahrenheit. The most favorable temperature will be different with different fuels and attendant should note the temperature at which operation is best and attempt to keep it reasonably close to that figure. The temperature can be held at that point by regulating the supply of water to the cylinder jacket by means of the valve provided for that purpose. The pump, piping and water jacket of engine must be drained when engine is not in use to prevent freezing and cracking of cylinder.

Fuel for oil engine should be strained at the time storage tank is filled. In some types of engines fuel is injected into cylinder through a spray nozzle. Irregular operation may be caused by foreign matter in the oil sticking in the spray nozzle or in the check valve in the injector pump. The small hole in end of spray nozzle must be cleaned occasionally.

If a loss of compression is noticed, piston should be inspected. The piston rings should be free in their grooves. If they stick, the compression or explosion will blow past them and the combustion will be poor, due to poor compression. Any accumulation of carbon which tends to stick to the rings should be washed out with gasoline.

EXAMINATION QUESTIONS FOR CARE OF ELECTRICALLY OPERATED PUMPS.

Q.—What are the two kinds of current generated?

A.—Direct and alternating current.

Q.—How would you distinguish between the two motors?

A.—The direct current motor will have a commutator and brushes, the alternating current motor will have neither commutator nor brushes.

Q.—How should a direct current motor be started?

A.—The arm of the starter should be moved slowly over the contacts from the "off" to the "on" position as the motor comes up to speed.

Q.—How should an alternating current motor be started?

A.—This type of motor is usually started with an auto-starter, the lever of which should be thrown first to starting position and held until motor has attained normal speed and then to the running position.

Q.—What would be the result of bringing the starter handle over quickly?

A.—The rush of current might blow a fuse, trip a circuit breaker or possibly injure the insulation of the motor windings.

Q.—What is the proper method of stopping both the Direct and Alternating current motors?

A.—By opening the motor switch.

Q.—When using a direct current motor how should the commutators be cleaned?

A.—With a rag moistened with signal oil.

Q.—What are the indications of overheating in a motor?

A.—A fried or charred appearance of the insulation of the windings, especially the armature.

Q.—What would indicate the proper temperature of motor?

A.—After running an hour or two the field coils and armature should be warm but not enough to be uncomfortable to the hand.

Q.—How often should motors be lubricated?

A.—Once a month.

Q.—How would you proceed to lubricate a motor?

A.—The oil should be drained from the boxes, the boxes cleaned and refilled with clean oil.

Water Tanks.

They should be filled at each pumping to prevent shrinkage of wooden tanks, deterioration in sheets of metal tanks, as well as to safeguard the water supply in case of accident to the pumping plant. Tank spouts and grab ropes must be maintained at standard clearance. Defects in spouts, valves or discharge pipes must be reported at once. Attendant must watch engines take water and report unnecessary waste. Damage to fixtures or appliances by engines taking water must be reported to the Water Service Foreman, giving date, train and engine number.

Water Columns or Stand Pipes.

Water columns should be inspected frequently and maintained in good working order. Lifting rods should be tightened, leaky glands repacked, locks and rollers adjusted. On double track, water columns should be swung in the direction of traffic and locks maintained in such position that they hold the water column parallel to the track.

Motor, control and pump should be inspected at least once each week, at which time all parts should be thoroughly cleaned, all contacts should be carefully inspected and seen to that they make and brake at proper time and that contact surfaces are clean, all wearing parts should be well lubricated with proper lubrication. Special attention should be given to motor bearings, building or room where motor is located should be kept clean and particular attention should be given to see that no papers or oily waste is left or allowed to collect in switch boxes or near motor or any electrical contact or wires.

Waste must not be used around commutator or brushes and gasoline or sandpaper must not be used to clean commutator. If motor sparks excessively the proper official should be notified.

Motor should be watched carefully for over-heating. The commutator should not be allowed to become worn or grooved by the brushes.

Any displaced wiring must also be reported. No attachments should be made to the wiring as serious damage may be done to the equipment and there is danger of personal injury. A fuse must never be replaced with anything but a proper fuse. If one of a higher ampere rating is used it may cause serious damage to the motor. The fuse is the electrical safety valve and should no more be tampered with than a steam safety valve. A test lamp should be used to find blown fuses, thus avoiding chances of electric shocks. A gage should be supplied to each alternating current motor to test the space between motor and field poles. If gage will not pass freely the bearings need immediate attention.

On pump motors controlled from a distance, the remote control starter located in the pump house should be tested frequently to see that it starts the motor properly. It should be inspected frequently and any badly burned contacts reported.

Appendix E.

(6) ORGANIZATION FOR RAILWAY WATER SERVICE DEPARTMENTS.

C. R. KNOWLES, Chairman, Sub-Committee.

Providing water for locomotives and other railway purposes is a feature of railway operation that varies more widely than any other department on American railroads, with the exception of a few of the larger railroad systems, no distinct water departments are maintained. While it is true that on small lines the work is not extensive enough to justify the employment of specialists, yet in would appear that there are but few roads that would not find it profitable to assign some one properly qualified to devote his attention to the problems of water service. On the majority of railroads the development of water supply and design and construction of water stations is not handled as a separate department, but is left to someone in the engineering department in connection with other duties. While the maintenance and operation of water stations usually comes under the Master Carpenter or Supervisor of Bridges and Buildings whose principal duties are along other lines entirely foreign to water service.

The many different methods of handling and apparent neglect of railway water supply is probably due to the fact that within comparatively a few years ago this department of the railroad was not considered of any great importance, as the quantity of water required was not great and the quality a matter that was given but little, if any, consideration. Conditions have changed with modern railway operation, which calls for careful, intelligent consideration of the many problems involved.

Establishing a water department organization does not necessarily mean that the division or local forces are materially changed where water service men are locally employed, and the miles of an organization exists, but rather that the local officers and engineering department are relieved of the duties incidental to the design and development of water facilities and the work placed in the hands of those trained along this particular line. That there is an urgent need for such an organization has been proven by the results obtained on roads that have established a department to handle this very important feature of railroad operation.

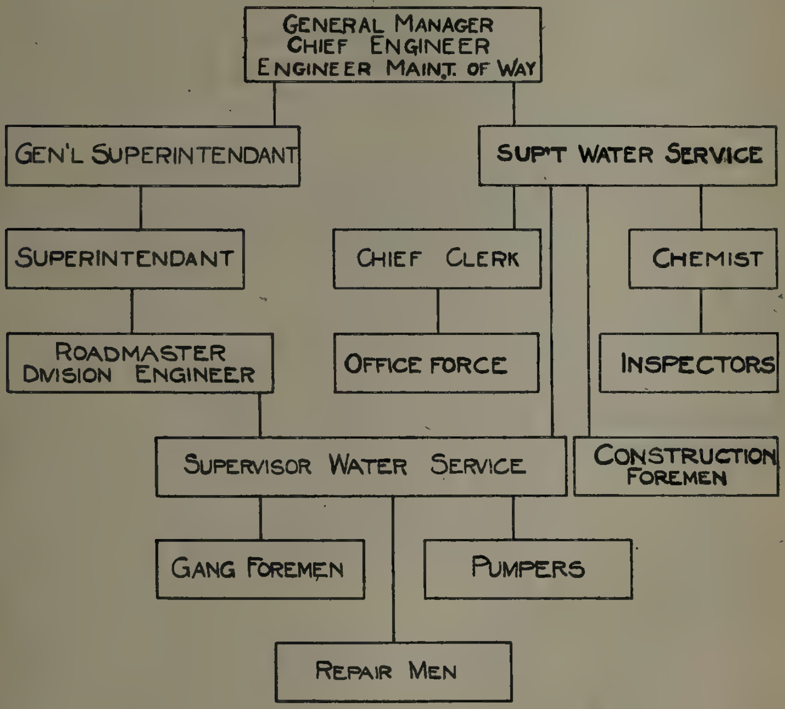
Inquiries as to the method of handling water supply were sent out to a number of railroads. Replies were received from 38 railroads representing a mileage of 136,991. The total number of water stations was 7816. Of roads reporting seven have a separate Water Department, while on twenty roads the water supply is handled by the Bridge and Building Department; on eight roads by the Divisional Water Department, and on three roads jointly by the Maintenance of Way and Motive Power Department. There was total of 415 treating plants reported, from one plant only on a number of roads to 108 on one road.

The graphical chart submitted herewith represents a complete water department organization and may be readily adapted to any road with such modifications as may be necessary for a road of greater or lesser mileage.

For example, where there are no treating plants in service the work of making water analysis would probably come under the Engineer of Tests or outside chemists, rather than a department chemist.

The chart as submitted represents the best practice in present water department organization on American railroads, and while it is not exactly typical to any particular water department organization, your Committee feels that it embodies the best features of the existing water department organization.

WATER SERVICE ORGANIZATION.



DIVISION WATER WORKS GANGS.

PERSONNEL AND LIST OF TOOLS AND EQUIPMENT FOR WATER WORKS GANGS, WHO WILL REPORT TO SUPERVISOR OF WATER SERVICE AND HANDLE CONSTRUCTION JOBS WHERE SUPERINTENDENT WATER SERVICE CANNOT FIND A WHOLE LINE GANG AVAILABLE.

1 Foreman.
1 Pipe Fitter.
2 Tank Carpenters.
5 Water Works Men.

LIST OF TOOLS FOR WATER WORKS GANGS.

Name.	*Amount.*
Axe, Single bit	2
“ Hand	2
Adze	2
Blades, Hack saw—12"	12
Blocks, Chain cyclone—one ton capacity	1
Blocks, Two pulley steel—Self lubricating for ¾" manilla rope	2
“ “ “ “ —Self lubricating for 1" manilla rope	2
“ Steel snatch—Self lubricating for 1¼" manilla rope	2
Bars, Pinch	5
Bars, Claw	1
Broom, House	2
Chisels, Track—With handles	4
“ Cold—¾"x7"	6
“ Roundnose—¾"x6"	6
“ Diamond point—¾"x6"	6
Coolers, Water—Five gallon	1
Cutters, Pipe—3 wheel No. 1	1
“ “ 3 “ No. 2	1
“ “ 3 “ No. 3	1
“ “ 3 “ No. 4	1
“ “ 3 “ No. 5	1
Derrick, Sashen Pipe ⅜" cable	1
Drills, Twist taper shank ¼"	2
“ 5/16"	2
“ ⅜"	2
“ 7/16"	2
“ ½"	1
“ 9/16"	1
“ ⅝"	1
“ 11/16"	1
“ ¾"	1
“ ⅞"	1
“ 1"	1
Drill Press, No. 1 for taper shank drills ¼" to 1" incl.	1
Die Plate, and bolt taps 81 C Bay State full mounted screw plate	1
Digger, Post hole	1
Dollies, Timber	2
Dies, Toledo Pipe No. 0	1
“ “ “ No. 1	1
“ “ “ No. 4	1

Name.	*Amount.*
Flags. Cloth—Red	4
“ “ Green	4
“ “ Yellow	4
“ “ Blue	2
Fuses, Red	6
“ Yellow	6
Files, 12" assorted ½ round	6
“ 10" “ ½ “	6
“ 12" “ flat	6
“ 10" “ “	6
Hammers, Claw	2
“ Machinist	3
“ Calking	3
Hooks, Lug	2
Jacks, Track and handles	2
“ Car Box 2x10 12 T	2
Kegs, Water	1
Lanterns, White	2
“ Red	2
“ Green	2
Oilers, Hand	2
Picks, Clay—With handles	12
Pots, Lead Pouring—No. 1 with 2 hooks each	2
Punch, Screw—With bar head and punch drills	1
Pump, Trench—With 12' 3" suction hose and strainer	1
Pipe, Reamer and tap ¼"	1
“ “ “ “ ⅜"	1
“ “ “ “ ½"	1
“ “ “ “ ¾"	1
“ “ “ “ 1"	1
“ “ “ “ 1¼"	1
“ “ “ “ 1½"	1
“ “ “ “ 2"	1
Rope, Manilla ¾"	500 ft.
“ “ 1"	500 ft.
Ratchet, Improved Parker Boiler No. 2 for taper shank twist drills ¼" to 1"	1
Saws, Hand	2
“ Cross cut	2
“ Hack 12"	2
Shovels, Track No. 2	6
“ Long handled roundnose	6
Spades, 16" square point tile	6
Scythe, Brush	1
Sledge, 16 lb. with handle	1
“ 12 lb. “ “	1
“ 8 lb. “ “	1
Tool Grinder, without special attachment	1
Tool Box, Section	1
Torpedoes	12
Tools, Yarning No. 1	2
“ “ No. 2	2
“ Calking No. 1	2
“ “ No. 2	4
“ “ No. 3	4
“ “ No. 4	4

Name.	*Amount.*
Vise, Parker Combination No. 4	1
" Malleable pipe No. 1	1
Winches, Hand Power size "A" tapered drum	1
Wheel barrows	3
Wrenches, Monkey 8"	2
" " 12"	2
" " 18"	2
" Stillson 8"	2
" " 10"	2
" " 14"	2
" " 18"	2
" " 24"	2
" " 36"	2
" Chain Ideal No. 2	2
" " " No. 3	1
" " " No. 4	1
" " " No. 5	1
" Open end—double headed No. 34	1
" " " " " No. 37	1
" " " " " No. 38	1
" " " " " No. 39	1
" " " " " No. 41	1

Appendix F.

(7) DEFINITIONS OF TERMS USED IN RAILWAY WATER SERVICE.

C. R. Knowles, Chairman, Sub-Committee.

Group "A"—Wells.

(1) Artesian Well.—A flowing well from which the water is caused to rise above the surface of the ground by a subterranean pressure.

(2) Deep Well.—A well having a depth of 100 feet or greater.

(3) Shallow Well.—A well less than 100 feet in depth.

(4) Drilled Well.—A well made by drilling or boring.

(5) Driven Well.—A well constructed by driving the casing and then removing the material inside the casing.

(6) Dug Well.—A well made by digging or excavating.

(7) Well Casing.—A pipe forming the wall of a well.

(8) Well Screen.—A perforated device, usually a slotted or wire-wound pipe for the admission of water into and the exclusion of other matter from a well.

Group "B"—Water Tanks.

(1) Tank.—A basin or reservoir above ground for the storage of liquids.

(2) Tank Tower.—That portion of the tank structure between the tank and its foundation.

(3) Tank Valve.—The valve for delivery of water from the tank.

(4) Outlet Pipe.—The pipe for delivery of water from the tank to the spout.

(5) Tank Spout.—An adjustable spout for delivery of water from the outlet pipe to the tender.

(6) Indicator.—A device for indicating the height of water in tank.

(7) Float Valve.—A valve operated by a float for controlling the height of water in tank.

Group "C"—Pipe Lines.

(1) Intake Line.—A line of pipe through which the water flows from the source of supply to the intake well.

(2) Suction Line.—A line of pipe through which water is drawn by suction to the pump.

(3) Drop Line.—A vertical line of pipe through which water is lifted out of a well.

(4) Discharge Line.—A line of pipe from the discharge of pump to tank, or distribution system.

(5) Service Lines.—Lines of pipe through which the water is distributed.

GROUP "D"—WATER COLUMNS.

(1) WATER COLUMN.—An apparatus for delivering water into the tender at a distance from the tank.

GROUP "E"—INTERNAL COMBUSTION ENGINES.

(1) INTERNAL COMBUSTION ENGINE.—A prime mover in which the power is derived from the explosive force of the fuel, compressed and ignited in a cylinder, acting directly against a piston.

(2) TWO-CYCLE ENGINE.—An internal combustion engine receiving a power impulse during each revolution.

(3) FOUR-CYCLE ENGINE.—An internal combustion engine receiving a power impulse during each second revolution.

(4) GASOLINE ENGINE.—An internal combustion engine using gasoline, naphtha or other volatile petroleum fuels.

(5) GAS ENGINE.—An internal combustion engine using natural or manufactured gas as fuel.

(6) OIL ENGINES.—An internal combustion engine that may be started and operated on a non-volatile oil of lower specific gravity than gasoline without passing the oil through a carburetor, mixing valve, or preheating the oil, in which the fuel is ignited by a bulb, tube or plate heated from previous combustion.

(7) DIESEL ENGINE.—An oil engine in which the combustion is due to the heat generated by compression.

GROUP "F"—WATER TREATMENT.

(1) UNTREATED WATER.—Water not subjected to treatment.

(2) TREATED WATER.—Water subjected to treatment.

(3) UNDERTREATED WATER.—Water to which insufficient chemicals have been added.

(4) OVERTREATED WATER.—Water to which an excess of chemicals has been added.

(5) INCRUSTING SOLIDS.—Matter in the water which forms scale on tubes and sheets of boilers.

(6) NON-INCRUSTING SOLIDS.—Matter in the water which does not form scale.

(7) SUSPENDED MATTER.—Matter in the water which may be removed by coagulation, sedimentation or filtration.

(8) AERATION.—Bringing the water into intimate contact with air in order to introduce oxygen for the oxidation of iron or organic matter, and for washing out gases and volatile odors.

(9) FILTRATION.—A process of passing water through layers of sand or other porous material for the removal of suspended matter or bacteria.

(10) SETTLING TANK.—A reservoir in which water is retained for the sedimentation of suspended matter.

(11) REAGENT.—A chemical used for the treatment of water.

(12) Hardness.—The quality of water caused by dissolved incrusting solids or by acidity.

(13) Sludge.—Resultant precipitant formed by sedimentation or by removal of incrusting solids in water treatment.

Group "G"—Pumps.

(1) Pump.—An apparatus for raising or transferring water or other fluids.

(2) Reciprocating Pump.—One in which the piston or plunger alternately draws the water in and discharges it from the cylinder.

(3) Single Acting Pump.—One in which one end of the plunger only acts on the fluid column.

(4) Double Acting Pump.—One in which the plunger acts upon the fluid column both upon the forward and return stroke.

(5) Piston Pump.—One in which a finished cylinder is closely fitted with a reciprocating piston.

(6) Plunger Pump.—One in which the reciprocating part is a solid plunger which does not come in contact with the cylinder walls, but enters the cylinder through packing glands.

(7) Direct Acting Pump.—One in which the piston is reserved by an impulse derived from itself at or near the end of each stroke.

(8) Rotary Pump.—One in which two revolving pistons rotate in a pump case which they completely fill; the pistons alternately draw in and discharge the water.

(9) Centrifugal Pump.—One in which the pressure necessary to raise the water is derived from the velocity of a revolving impeller.

(10) Air Lift.—An apparatus for introducing compressed air into a well and thereby raising water out of the well.

Appendix G.

POLLUTION OF WELLS FROM OVERLYING OR ADJACENT CINDER DEPOSITS.

By W. C. Curd.

The data submitted below, recently collected by me in an investigation of ground or well water for locomotive boiler use in district surrounding East St. Louis, Ill., presents some points in regard to the detrimental effect of cinders on quality of water in shallow wells, which are out of the usual line of thought on such matters and prompts me to suggest to your Committee a more exhaustive investigation of the subject.

Opinions on the poor quality of East St. Louis well water for boiler use have been very freely expressed for several years back by chemists, who have sampled the water at numerous locations. Occasionally reports in conflict to the general opinion have been found, but it appears no attempt has ever been made to find a cause for the disagreement.

During the early part of the past Summer, while investigating ground water conditions in East St. Louis, I personally took samples of water from seven wells at widely separated points in that district and submitted them to a chemist for analyses with the following result:

Sample No.	No. 1	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Total Solids	23.34	26.35	58.60	41.78	34.19	89.20	26.30
Total Hardness	16.3	16.5	28.3	22.5	18.6	29.5	13.0
Carbonate Hardness	16.3	16.5	18.2	18.3	16.0	24.8	13.0
Sulphate Hardness	0.0	0.0	10.1	4.2	2.6	4.7	0.0
Total Alkali Solids	7.04	9.85	30.4	19.2	15.5	59.7	13.3

All of these waters came from wells of substantially the same depth and at time of sampling notation was made of character of surface covering at each well site, which information is given below:

Sample No. 1. Was taken from well at plant having fuel consumption of small amount. Ground surface around plant and particularly in vicinity of well site was comparatively free of cinders.

Sample No. 3. From well where no cinders have been deposited.

Sample No. 4. From plant where entire property was surfaced with cinders several feet deep.

Sample No. 5. Some cinders were visible, but none deposited recently or under three or four years.

Sample No. 6. About same conditions as found at No. 4.

Sample No. 7. Large area covered with cinders and continued daily deposits being made.

Sample No. 8. New plant and no cinders found around boiler room or well site.

In another part of the district a test hole was put down to depth of 87′ below surface, but sample was taken from depth of but 20′ and analyzed as follows:

	Grains per Gallon
Total solids	23.90
Organic matter	0.83
Mineral matter	23.07
Silica	1.50
Iron oxide and alumina	0.05
Calcium carbonate	4.44

	Grains per Gallon
Calcium sulphate	10.99
Magnesium carbonate	2.03
Magnesium chloride	3.45
Sodium chloride	0.61

To my knowledge this did not represent a typical water for the location and I had a second test hole put down (6′ from the first), this time to depth of 78′. Hole was pumped two hours and sampled at full depth, and analyzed as follows:

	Grains per Gallon
Total residue per gallon	23.46
Composed as follows:	
Calcium carbonate	13.50
Magnesium carbonate	3.15
Magnesium sulphate	1.26
Oxide iron, floating	0.32
Sodium chloride	5.23
Total Scale Making Salts	18.00

At time second hole was being pumped a chemist was on ground and made soap tests on water from both Hole No. 1 and Hole No. 2 with the following result:

	Grains per Gallon.	
	Hole. No. 1	Hole No. 2
Hardness	17.0	17.0
Alkalinity	13.6	18.8
Sulphates	3.4	0.0

Since the second sample from Hole No. 1 showed considerable improvement over first one taken some weeks previous, the chemist investigated and found Hole No. 1 was located in a depression near a pile of cinders for use in surfacing tracks, and that two days prior to the drilling of Hole No. 1 a rain had occurred which drained through the cinders into the depression.

After Hole No. 1 was sampled, it was fitted with a small pitcher pump to furnish water for concrete gangs and it was well pumped for two or three weeks prior to the second sample, the results of which are given in the preceding paragraph. This afforded opportunity for the water to clear up. The fact that Holes Nos. 1 and 2 were only 6′ apart and produced such radically different water, would indicate the direct effect of cinders.

Another location with which you are familiar is the Missouri Pacific wells at Dupo, Ill. The Dupo shop grounds, as you know, are surfaced over a very large area with cinders. Water from wells put down in 1908 gave following analysis in 1908 and again in 1915:

	Grains per Gallon.	
	4-8-15	11-8-15
Calcium carbonate	10.96	16.42
Magnesium carbonate	4.12	4.97
Calcium sulphate	0.0	0.0
Magnesium sulphate	0.0	4.86
Oxide iron and alumina	0.15	1.13
Silica	1.64	1.68
Alkali chloride	0.34	1.74
Alkali sulphate	0.10	...
Sodium carbonate	0.24	...
Organic matter	2.37	...
Total Solids	19.92	30.80

A second well put in at Dupo within about 50′ of old wells the early part of this year tested out at rate of 1500 gallons per minute and gave following analyses when sampled at a four months' interval:

	Grains per Gallon. 4-12-17	 7-12-17
Calcium carbonate	13.50	22.50
Magnesium carbonate	7.25	0.0
Calcium sulphate	0.0	3.91
Magnesium sulphate	0.0	2.21
Oxide iron and alumina	1.50	0.21
Silica	0.25	0.28
Alkali chloride	0.70	1.32
Alkali sulphate	0.20	...
Sodium carbonate	0.00	...
Organic matter	0.10	...
Total Solids	23.50	30.43

R. C. Bardwell, Chemist, Missouri Pacific Company, advises when hauling water to Fort Scott, Kas., by work train the past February he analyzed the water in the tanks and found same to have a total hardness of 20 grains. This water was discharged from tank cars into a ravine but in reaching same had to flow through cinders along track and right of way. An analysis of water after it reached the ravine showed total hardness of 58 grains, an increase of 38 grains, directly traceable to the cinders.

Although not directly along the same line, the following are some figures given out by Geological Survey, State of Illinois, on percentages of well waters condemned by Water Survey, classified by depth, for years 1907 to 1914 inclusive:

Depths.	Number examined.	Number condemned.	Per cent.
Less than 25′	1674	1264	76
25′ to 50′	2316	1465	63
50′ to 100′	1094	345	32
More than 100′	2800	347	12

In view of these references it would appear much could be gained by a more careful selection of well sites, so as to get beyond the reach of cinder effect.

In the event your Committee should take up this question for investigation, I shall be glad to furnish you any further data I may collect.

REPORT OF COMMITTEE VI—ON BUILDINGS.

M. A. LONG, *Chairman;*	G. H. GILBERT, *Vice-Chairman;*
GEO. W. ANDREWS,	E. A. HARRISON,
D. R. COLLIN,	A. LARSEN,
W. H. COOKMAN,	J. W. ORROCK,
C. G. DELO,	S. B. PHILLIPS,
W. T. DORRANCE,	R. V. REAMER,
K. B. DUNCAN,	C. W. RICHEY,
C. H. FAKE,	JOHN SCHOFIELD,
A. T. HAWK,	Z. H. SIKES,
F. F. HARRINGTON,	W. J. WATSON,

Committee.

To the American Railway Engineering Association:

Your Committee on Buildings respectfully submits herewith its report to the Nineteenth Annual Convention.

The following subjects were assigned the Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, with especial reference to appropriate definitions.
2. Report on coaling stations.
3. Report on freight-house and passenger station scales.
4. Report on ash pits.
5. Report on a classification of buildings on the basis of "Specification Types," and upon the use of the "cubic foot," "square foot" and "bill of particulars" methods for ascertaining the approximate cost of new construction.
6. Report on safety-tread devices for stations exposed to the elements.
7. Report on the general subject of roadway buildings.
8. Report on design and merits of high and low platforms at passenger stations.
9. Report on design of shop buildings.
10. Report on comparison of "umbrella" versus "butterfly" sheds at through stations.

COMMITTEE MEETINGS.

Meetings of the General Committee were held as follows: At New York, June 12th and 13th, and December 4th and 5th; at Chicago, January 15th.

(1) REVISION OF MANUAL.

On this subject the Committee has no recommendations to make in the Manual at this time. A series of definitions pertaining to the subject of "Buildings" are submitted in Appendix A as a progress report.

(6) SAFETY-TREAD DEVICES FOR STATIONS EXPOSED TO THE ELEMENTS.

In Appendix B the Committee submits a report on this subject, together with conclusions and recommendations, which are submitted for adoption and publication in the Manual.

(8) DESIGN AND MERITS OF HIGH AND LOW PLATFORMS AT PASSENGER STATIONS.

In Appendix C the Committee submits a report on this subject, with conclusions, and recommends their adoption and publication in the Manual.

PROGRESS REPORTS.

The Committee reports progress on Subjects (2), (3), (4), (5), (7), (9) and (10).

CONCLUSIONS.

1. The Committee recommends the definitions of terms given in Appendix A be received as a progress report.
2. It is recommended that the conclusions and recommendations given in Appendix B be approved and published in the Manual.
3. It is recommended that the matter in Appendix C be adopted and published in the Manual.

RECOMMENDATIONS FOR FUTURE WORK.

The Committee recommends that Subjects 2, 3, 4, 5, 7, 9 and 10 be reassigned for the coming year.

Respectfully submitted,

The Committee on Buildings.

Appendix A.

DEFINITIONS.

STATION.—A building for the accommodation of passengers or freight at termini or at intermediate points.

PASSENGER STATION BUILDING.—A building serving as a starting point or stopping place for passengers.

FREIGHT STATION BUILDING.—A building used exclusively for the receipt, storage, transfer, or delivery of freight.

COMBINATION STATION BUILDING.—A building used jointly for the accommodation of passengers, and for the receipt and delivery of freight.

TRANSFER SHED.—A long platform, generally covered and placed at distributing points on railroad system, where loads for miscellaneous destination may be redistributed into full carloads for final delivery. These are sometimes combined in a freight house layout and called transfer platforms.

TRANSFER CRANE.—A stationary crane, having side supports and bridge framed together, spanning tracks, and used to facilitate the handling of heavy commodities from cars to tracks or vice versa.

GANTRY CRANE.—A power-driven crane with supports and bridge framed together, made to travel on grade level, spanning tracks and running parallel to same, used for loading or unloading heavy commodities.

SHOP BUILDINGS.—Various structures for the making of repairs to locomotives, engine erecting, boiler and blacksmith work, car building and repairing, dry kiln for lumber, and other branches of work.

ROUNDHOUSE.—A semi-circular building, containing locomotive stalls centering toward a turntable or yard. These houses equipped with drop pits for cleaning and repair of locomotives; truck, driver and tender wheel pits at right angles to drop pits and covering at least two stalls for dropping the several wheels mentioned. Houses are sometimes fitted with traveling or stationary cranes for removing various parts of locomotives.

When house is built in rectangular form, the name "roundhouse" would hardly apply. The name "enginehouse" would no doubt be more suitable.

TURNTABLE.—A revolving platform for turning locomotives or cars.

TRANSFER TABLE.—A traveling platform driven transversely for moving locomotives or cars from one parallel track to another.

COALING STATIONS.—A structure or appliance for the storing and delivering of coal to tenders.

SAND HOUSE.—A structure for the drying and storing of sand and delivering same to locomotives by gravity.

OIL HOUSE.—A structure above ground or basement pit for the storage of oil tanks containing the various oils used for locomotives, cars and shop requirements.

WATER STATION.—A large receptacle or structure, built of wood, concrete or metal, for the storage of water supplying engine tanks and yard facilities.

Pump House.—A building at or near a water supply station, containing the pumping apparatus.

Signal Tower.—A tower or structure from which to display a semaphore or other signal or to operate mechanical signals approximately to same.

Interlocking Tower.—A tower or structure containing the mechanism for operating the switches and signals in yards when of the interlocking type.

Hose House.—A structure containing hose and other equipment in yards or other places for fire protection.

Watch Box.—A shelter at road or street crossing to protect the crossing watchman.

Tool House.—A storage place for shelter and safety of tools or other equipment used for track maintenance.

Section House.—A structure for housing section foreman and family.

Bunk House.—A structure for housing track or other railway laborers.

Subways.—An underground passageway at certain types of passenger stations leading from main building across under tracks. Where intermediate platforms occur, inclines or stairways are provided leading from main passage up to train floor level. By this arrangement passengers are enabled to reach or leave trains without crossing tracks.

Subways are sometimes used for other purposes, such as handling of baggage in place of stairs or inclines. Elevators are installed at certain points for raising and lowering trucks from sub to main floors of building.

Stock Yard.—An enclosure for stock, usually built with a running board fence. The enclosure is subdivided into pens facing on alley or runway. This runway connects up with incline and loading platform. Pens are sometimes fitted with feeding racks and water connections for taking care of stock till ready for loading, and shipping to destination.

Power House.—A structure containing apparatus for supplying power, air, steam and current for various purposes.

Sub-Station.—A structure containing apparatus for transforming and distributing electrical current.

Warehouse.—A building used for the storage of freight.

Store Houses.—Buildings for the storage and distribution of miscellaneous materials used in railway work. Oil basements are sometimes built in connection with store houses. Tanks are placed in underground basement and filled by gravity from tank cars. Oil is distributed from main floor by self-measuring pumps.

Scrap Bins and Platforms.—A facility for collection of cuttings and other merchantable scrap until disposed of.

Car Repair Sheds.—Buildings grouped in connection with car repair yards for shop work of various kinds in connection with same. These buildings are sometimes built with open sides, when more than one track, house provision should be made for ample light from overhead for lighting working space between lines of cars.

Ice House.—A structure for the storage and distribution of ice for trains or other uses and protection of perishable freight.

Office Building.—A structure for the accommodation of clerical, telegraphic, engineering or other forces.

Rest Room.—A structure containing rest and recreation rooms, sleeping quarters, lunch rooms, lockers, baths, etc., for the accommodation of trainmen and other employees at terminals.

Pier (Dock or Wharf).—A covered or open structure extending out into the navigable waterway, or parallel to shore of same for the receipt or delivery of freight from or to vessels with tracks on or adjacent to same, where used in connection with railway terminal.

Locomotive Washing Platform.—A slightly depressed platform under engine tracks in terminals. These are used for washing and cleaning engines, and are drained to sewer.

Thawing Shed.—An insulated, heated structure used for thawing out frozen commodities in bulk at export terminals.

Monitor.—A raised portion of roof to obtain light or ventilation from vertical sides or ends.

Pent House.—A projection above the roof of a building to provide exit onto roof. House elevator, machinery or other similar purposes.

Bent.—A structural unit in a trestle or framed structure, placed at regular intervals.

Platforms.—A raised walk upon which passengers alight from railroad cars. Platforms are built of wood, concrete, brick or cinders.

Saw Tooth Truss.—A special form of roof construction built in bents having a vertical or slightly sloping face. This portion of bent is glazed and usually built facing the north, so as to obtain light without sun rays.

Elevators.—Buildings used for storage, cleaning, grading and distribution of grains.

Train Shed.—Usually built covering two or more tracks. Roof and sides generally fitted with skylights or prismatic skylights and slots for ventilation.

Butterfly Sheds.—Usually a one-post structure having spreading eaves with drainage sloping back to center of same.

Umbrella Sheds.—Same as butterfly, but roof slopes to outer edges. These sheds are built on depot platforms between lines of track and afford only partial protection to passengers.

Scales.—An apparatus for weighing freight and baggage. In freight houses the dial scales are generally used. They afford quick reading of weights, and tend to rapid handling of loads over scale platforms. Track scales are used for weighing loaded or empty cars.

Scale House.—A small structure generally built in connection with track pit and scales. Scale beams are brought up inside of building.

Appendix B.

(6) PROVISIONS TO INSURE SAFE WALKING IN AND ABOUT PASSENGER STATIONS.

G. H. Gilbert, Chairman, Sub-Committee.

The managements of American railways have made a wonderful record during the last decade or two in safeguarding the lives of the public traveling upon trains. They should seek equal reputation for safeguarding the lives of passengers in and about stations, by the use of those provisions which experience has shown to be helpful, and to which so much attention is being directed by the "Safety First" movement of recent years.

Formerly, shock and horror over loss of life was associated in the public mind largely with railroad wrecks. Doubtless, this was due to the spectacular manner in which lives were lost, and the prominence immediately given such accidents by the daily press. Even loss of life in fires and elevator accidents seldom had equal news value, nor was of such national interest. Spurred on by this public consciousness, the railway managements have used every possible means at their disposal to render the lives of passengers on trains wholly safe. Through the use of the air brake, modern signal systems, improved rolling stock, and in countless other ways, the lives of railroad passengers have been so safeguarded that to-day statistics show, and it is generally known, that railroad traveling is as safe, if not safer than any other form of transportation, ordinary walking included.

To-day, the great stress laid upon safety of human life by the "Safety First" movement has, to some extent, broadened the outlook of the public, and brought a realization that the great need for improvement in safeguarding life lies in the ordinary risks of the industrial world, and those incidental to the common activities of life. The "Safety First" movement, recognized as a wonderful humanitarian force and as yielding results economically sound from a purely business viewpoint, has been adopted not only by large industrial corporations, but also by governmental bodies and labor organizations seeking to improve the working conditions and safeguard the lives of workmen. The attention given this movement has centered largely upon the causes of accidents and the resultant loss of life, or the character and extent of injuries received. Statistics obtained in this manner, it is surprising to note, show that the great majority of accidents are due to trivial, commonplace causes. Accidents while walking, due to colliding of persons with each other, or to slipping or stumbling on stairways and on level surfaces, are of alarming economical importance where traffic is dense. The American public can reasonably expect that railway passenger stations shall be as free from risk of this character as possible, and that provisions to safeguard walking in and about stations shall be, at least, as good if not better than can be found elsewhere.

Careful attention should be given to the experience of those railroads handling heavy traffic, and to the statistics of those agencies which are concerned with and seek to reduce the risk of personal injury, and are engaged in this work along statistical and scientific lines. The transportation agencies of large cities, that is, the great railroad systems and the elevated and underground electric roads, have found it necessary to give their best attention to methods to insure safety in handling large crowds in rush hours going to and from passenger stations and while waiting in stations and on platforms. The experience of these companies may well be used by the railroads generally throughout the country to avoid certain recognized causes of accidents in and about station buildings, and to safeguard the public as much as possible against personal injury from slipping, tripping and falling. The railroads handle through passenger stations day in and day out enormous crowds of hurrying, bustling people, and the responsibility rests upon the railroad companies to use in handling these crowds, all safeguards which experience shows are needed, and which may be known to be preventives, if due attention is given to the vast amount of statistical information which gradually is being accumulated by insurance companies, safety bureaus of large corporations, and compensation or other workmen's bureaus of the various states. Requirements imposed by law regarding the handling of people in crowds are concerned almost wholly with school children, factory employes, and crowds in theaters or auditoriums. .

When railroads construct depots, or extensively alter existing stations, they should be guided by these lawful requirements and incorporate in the plans as many safeguards as practicable. The cost of safety provisions is generally insignificant; the main requirement being that consideration and thought be given to certain features of safety, which are simply matters of common sense to those with experience in such matters. A direct effort should be made to eliminate and reduce all recognized risks of personal injury as shown by the experience of insurance companies and safety bureaus. Many little details of construction can be changed, and many standards of maintenance improved, with beneficial results.

The risk to pedestrians of accidents resulting in personal injury, particularly those due to slipping, tripping and falling is, doubtless, many times greater around passenger stations than it is on ordinary sidewalks or other crowded places in cities. There are few, if any, other places with such crowds in continuous motion, where the thoughts of the individuals are so fixed upon matters foreign to their personal safety. The person who travels infrequently is often worried about tickets, baggage, arrival and departure of trains, or about other members of his or her immediate family; while the more experienced travelers are apt to catch trains at the last minute, or hustle away from trains to keep engagements; thus having that mental attitude that tends to carelessness and absent-mindedness. Not only must safeguards be thrown about the ordinary careless or normally healthy individual, but due consideration must be given to the safety in crowds of the sick, the aged and the infirm, the small child, the mother with baby in arms and possibly other children dragging behind, and also the foreigner, who, perhaps, cannot read. As trains are about to leave, late-comers with heavy and big bags or suitcases, rushing about, are a potential menace to all who may be in their paths, and similar conditions exist with inbound passengers who may have arrived on late trains and who rush for other trains or to keep appointments already overdue.

People around passenger stations are injured in many ways—they cross tracks and are hit by moving trains, they stand so close to the edge of platforms that either by reason of carelessness or by being shoved by crowds, they are hit by engines or cars and they collide with baggage or express trucks, or are hit by packages falling from them; they are sometimes injured by colliding with each other, particularly when carrying large hand baggage. When boarding or leaving trains, they sometimes misstep or slip, they stumble and fall on stairways, and even on level surfaces such as platforms, sidewalks and waiting-room floors.

All such accidents can be considered in two groups:

(1) Those due to colliding of persons with each other, or with trains, trucks, hand baggage, etc.

(2) Those due to slipping and tripping on stairways, ramps, platforms, level surfaces, etc.

The colliding of persons with objects or with each other is the direct result of cross currents of travel, which can be either partially or wholly avoided by proper arrangement and layout of stations, and by proper safeguards for handling crowds. This assumes that the character of the future traffic and needs of the people to be handled are well known and anticipated at the time plans are made. Fortunately, all those arrangements which make for convenience and speed in handling crowds also tend to safety, so that with few exceptions, a study of means to handle people rapidly will also be a study to handle them safely.

At large terminal stations, where density of traffic justifies such arrangements, avoidance of cross currents of travel and separation of the hustling, bustling traveler from the person at leisure can be largely accomplished as follows:

(1) By separating inbound and outbound traffic as much as possible so far as main currents of travel are concerned.

(2) By separating through traffic from local, or suburban, traffic.

(3) By furnishing for inbound traffic as direct exits as possible to carriage ways and stands, to sidewalks of main thoroughfares, and to electric cars. Similar arrangements can be made for outbound traffic, so that most of the crowds will not have occasion to pass through the main waiting room, or even traverse any great length of concourse.

(4) By locating the waiting rooms for men and women, lavatories, ticket offices, baggage checking windows, and parcel windows so as to be readily accessible from all main lines of travel, with particular attention to locating entrances to such conveniences away from corridors and walkways which are crowded in rush hours.

(5) By separating and grouping people by signs or bulletins, and doing this as early as possible, particularly in concourses and in handling people gathering about gates leading to the trains. There should be large signs to guide a person's travel as soon as he enters a concourse, particularly to keep him from passing through crowds gathered near train gates. The use of small signs to convey information in concourses is the cause of much confusion and unnecessary hurried travel.

To guide crowds of people by information given verbally or audibly is not very satisfactory, even when such information is given simultaneously by annunciators in many parts of a station. The intelligence of people should be utilized by signs, lights and bulletins. The giving of information audibly will be improved if proper attention be given in station design to acoustics. Many concourses are needlessly crowded by people waiting for delayed trains, often grouped where they interfere with inbound passengers, when the same people would prefer to sit in main waiting rooms or stand around scattered instead of in dense groups if suitable bulletin notices were furnished and prominently displayed.

At most large stations, colliding of passengers with baggage and express trucks could have been either wholly or largely avoided at a reasonable expense if, at the time the original plans were made, this matter had been deemed of sufficient importance. At one depot, alternate platforms are used for trucking purposes only and at a few other depots there is practically full separation of passenger travel and trucking. However, most of the union depots recently built are planned merely to reduce interference to as great an extent as possible. This is generally accomplished by the use of elevators located at each end of the regular passenger platforms, so that baggage, mail and express can be taken to subways or overhead passageways not used by passengers.

These matters are so self-evident and of such general convenience that it would seem that suitable arrangements would have been incorporated in the plans of any large station building during the last ten or fifteen years. Yet, it is easy to find many instances where apparently these provisions for safety and convenience have not been given very serious consideration.

In choosing locations and making plans for small, or way, stations, especially where there are two or more tracks, the following safety features should not be ignored:

(1) Stations should be located, if possible, on that side of the railroad from which the greater number of passengers will arrive and depart, if there are crossings at grade for either vehicles or pedestrians.

(2) A location is desirable where it is possible to provide nearby

a subway or overhead structure, either at the time of construction or later as traffic becomes heavier.

(3) Intertrack fences can be used, extending far enough to make it more inconvenient to cross the tracks than to use provided avenues of travel.

(4) Overhead structures or subways for the use of passengers should preferably be provided in connection with intertrack fences.

(5) Island platforms can be used.

(6) Dead lines on platforms can be used.

(7) Fences, or gates, should be so connected to station buildings so as to keep people off of platforms, except when trains are due to arrive or depart.

When way stations must be located in the vicinity of grade crossings, as much clear distance as possible should be left between the street and the station. The arrangement of buildings and tracks should be considered with the object of providing a clear view of approaching trains, and also of giving an engineer a reasonable outlook. The location of a station abutting directly upon a street crossing tracks at grade, constitutes a death trap alike to people in vehicles and to pedestrians, even though gates are provided. The separation of traffic at way stations on double-track roads and the observance of many of the safety provisions above mentioned are illustrated at many of the modern stations built by such roads as the Delaware, Lackawanna & Western Railroad, Pennsylvania Railroad, and New York Central Lines, especially on four-track lines. Some of these safety provisions have been used in connection with very attractive architectural and landscape gardening features. The following articles, descriptive of various station arrangements, may be of interest:

Railway Age Gazette,	March	6, 1914—	Union Station, Wichita, Kansas.
" " "	July	10, 1914—	New York Central Station, Utica, N. Y.
" " "	Nov.	17, 1916—	Union Station, Dallas, Texas.
" " "	Jan.	30, 1914—	Great Northern Station, Minneapolis, Minn.
" " "	Jan.	9, 1914—	Michigan Central Station, Detroit, Mich.
Engineering Record,	Dec.	25, 1915—	Southern Pacific Station, Los Angeles, Cal.
" "	Nov.	4, 1916—	Proposed Union Station, Chicago, Ill.
Engineering News,	April	1, 1915—	Union Depot, Denver, Colo.
" "	July	30, 1914—	Jersey Central Station, Jersey City, N. J.

Your Committee endeavored to compile data showing the practice throughout the country as to separation of traffic, but the reports received were incomplete, and if published, would be misleading. Such information as was obtained has been compiled in blueprint form, and copies, if desired, can be obtained from the Chairman of this Committee. The table given below shows, for certain selected lines where two or more tracks are in use, the total number of way stations and the proportion where traffic is largely separated by subways, intertrack fences and similar arrangements. Most of the separation, however, is made on those portions of the lines where there are four tracks; in fact, reports received show that generally for unimportant way stations on double track, there is very little separation of traffic:

Railroad.	Line.	Total number Way Stations.	Number where traffic is largely separated.
P. & R.	New York to Reading	71	27
P. & R.	Philadelphia to Atlantic City	38	17
N. Y. N. H. & H. R.	Boston to New York (Shore Line)	112	50
Pennsylvania	New York to Pittsburgh	212	120
C. & N. W.	Chicago to Omaha	104	12
C. & N. W.	Chicago to Milwaukee	38	26
C. R. R. of N. J.	Jersey City to Scranton	90	21
N. Y. C. Lines	New York to Buffalo	127	93
N. Y. C. Lines	Buffalo to Chicago	123	8
B. & A.	Boston to Albany	63	3
B. & O.	Philadelphia to Washington	60	15

In connection with the matter of safety of passengers while waiting on platforms at way stations, the replies received from the various roads indicate that reliance is placed mainly upon the use of fences and gates to keep passengers off of platforms until such time as they can be allowed to use platforms without risk from through trains. A number of roads use dead lines. The N. C. & St. L. Ry. paints a line 4 in. wide located 4 ft. from the edge of the platform, with the words, "Safety First." The Rock Island also places dead lines 4 ft. from the edge of the platform. The Frisco places them 9 ft. 6½ in. from the center line of track.

Passengers using car steps at a low station platform, sometimes slip or fall either on the car steps or by not stepping properly on the step box when used; sometimes they even step between the edge of the platform and the car step. The location of the edge of the platform with reference to the car steps and the height of the platform with reference to the lowest step is, therefore, important from a safety standpoint, especially in view of the large number of personal injury cases which occur while passengers are boarding or leaving trains. The practice of railroads throughout the country in regard to elevation of platform relative to the top of rail shows one group of roads placing the platform level with top of rail, another group using a distance of 3 in. to 4 in., and a third group using 6 in. to 7 in. The distance from center of track to edge of platform varies generally from 4 ft. 3 in. to 5 ft. 4 in., with 5 ft. 0 in. largely used, but with many roads using about 4 ft. 6 in. One road even extends certain kinds of platforms out against the rail. There is equal lack of uniformity in the location of car steps.

A great deal of modern passenger equipment either has steps with three treads with the bottom step 22 to 23 in. above top of rail, or else has another step which brings the bottom step about 15 to 16 in. above top of rail. With the latter construction, the edge of the bottom step is a few inches short of 5 ft. from the center line of track.

The location of platform with reference to center of track involves so many clearance features, and is so dependent upon car construction that your Committee does not feel warranted in making any recommendations as to the proper location of the platform. However, so far as the location of platform with reference to the lowest car step can be determined by considerations of safety to passengers, it seems evident to your Committee that the car steps should extend, if possible, out to the edge of the platform, and that it should be possible to step off the car and down to the platform without using a step box, and without a greater vertical drop than is given by the risers of the car steps. Many of these risers are about 9 in. Clearances adopted for third rail construction make it convenient (see page 1256, 1917 Proceedings), although possibly not strictly necessary for the tread of the lowest car step to be not less than 15 in. above top of rail. It, therefore, would seem that if the step from car to platform should not exceed the riser of the car step, that the elevation of station platform should be, from this viewpoint alone, not less than 6 in. above top of rail. However, as above indicated, it is questionable to what extent the location of station platforms with reference to car steps can be determined, purely upon the basis of a desirable arrangement from the viewpoint of safety and convenience to passengers.

The use of high station platforms, level with car platforms, would be ideal from the viewpoint of both speed and safety in handling passengers, if only the open space between car and station platform were bridged over, and free from risks of slipping and stumbling. Where such platforms are now in use, it is necessary to caution passengers continually in such words as, "Watch Your Step," to keep them from carelessly stepping in the open space. While at subways and elevated electric roads this space can be kept very narrow, as the dimensions of rolling stock are fixed; yet, on railroads, this space may be quite wide due to the necessity of interchanging equipment and the lack, in this country, of standardization and restrictions in the size of rolling stock. At terminal and way stations, where only passenger traffic is handled, the high platform is much to be preferred. It is used at both the Grand Central and the Pennsylvania stations in New York City; and these installations should control, doubtless, the location of the edge of the platform with reference to the center of the track. It is not likely that the Pullman Company nor many of the larger railroad systems will build much passenger equipment too large to be handled upon occasion at these modern terminals. The distance from edge of platform to center of straight track at the Grand Central station is 5 ft. 5 in.; and at the Pennsylvania station is 5 ft. 3 in. At other stations on the Pennsylvania, equipped with high platforms, where tracks are used as running tracks by freight trains, it is 5 ft. 5 in.

The advisability of using high platforms at way stations, where through passenger and freight trains pass at high speed, is questionable. It is almost a necessity for quick and safe handling of many people at suburban and transfer stations, but the use of such platforms restricts the interchangeability of freight equipment, may prevent the special handling of extra wide loads, and may occasion serious and great loss of life with derailments or faulty equipment.

There is practically no uniformity in the location of either high or low platforms, and probably there will not be until the size of rolling stock, and the construction and location of car steps and car platforms has been standardized throughout the country. Until that time, the hazards of injury to persons boarding and leaving cars can only be reduced by the use of safety treads, well designed step boxes, and the use of porters or flagmen at all steps to assist and caution passengers.

The hazard of slipping, tripping and falling always exists with steps or stairways, but the chances of personal injury are increased many times when people collide with each other or with objects on stairways or ramps. This sort of collision should be recognized as extremely dangerous, and as almost wholly avoidable by the observance of those regulations and laws framed primarily to save life in times of panic, due to fire. This matter will be discussed later in connection with specifications for safety provisions in the design of stairways.

Slipping, tripping and falling of persons on level surfaces, as well as on stairways, is much more common and far more serious and economically important than is commonly understood. People trip over the slightest projection above the general walking surface, they stumble over low objects and hit against projections. They slip on smooth and worn iron parts, on vault lights, worn places in floors; in fact, a certain slipping hazard seems to be incidental to even walking on unobstructed level surfaces in good maintenance condition.

This slipping and tripping hazard should be given careful attention. The lack of emphasis upon it in the past is due, doubtless, to the fact that deaths and injuries from falls are so commonplace, and such a part of every-day life that they are without spectacular features or of more than local interest unless the persons injured are people of note.

Your Committee has endeavored to secure statistical information to show the necessity and economic justification for expenditures to reduce this hazard. To this end, the Committee corresponded with various accident insurance companies, large corporations and the various state industrial compensation boards. Most of such bodies have now united upon a common form for reporting accidents as to cause, so that a great deal of statistical data should be available within the next five years. At the present time, such data is scattered in many reports and cannot be well summarized. However, such information as has been obtained probably indicates what a more complete and extended report would show.

Bulletin No. 5, Bureau of Safety, Sanitation and Welfare of the United States Steel Corporation, shows that of 70,702 accidents classified as to cause, 7.73 per cent. were due to falls of persons; 59.9 per cent. of the falls resulted from slipping and tripping on the ground level, and 24.6 per cent. from slipping and tripping elsewhere, the balance being falls from scaffolds and ladders, or into unprotected holes.

The report of Accident Prevention Committee of the National Electric Light Association, dated May 22-26, 1916, shows statistics from 65 contributing companies, covering a period of about three years, and including only accidents to employes; of 5944 reported accidents, 16.2 per cent. were due to slipping, tripping and falling. There were only two other causes resulting in more accidents; namely, handling tools and handling material, which combined, total 38.1 per cent. of the reported accidents. Of the above mentioned 5944 accidents, 22.8 per cent. were due to slipping or falling on the level, 9.3 per cent. on stairs, and 13.6 per cent. over obstructions. Of 685 non-fatal accidents, slipping, tripping and falling caused 28.4 per cent. of the loss of time, exceeding by 7.6 per cent. the loss of time from any other class of accidents. The average loss of time for non-fatal slipping and tripping accidents was 11.3 days.

An accident insurance company reports that of 128,326 accidents happening "to careful people," i. e., people who are careful enough to appreciate the advantages of accident insurance, there was a total of 24,191 accidents due to falls. Of these 24,191 falls, those on pavements amounted to 10,940, or 45.2 per cent. of all falls, and 8.5 per cent. of total accidents reported. There were also 4,289 falls on stairs and steps, making the percentage of falls on pavements and steps equal to 11.9 per cent. of the entire number of accidents. The amount paid for these 15,000 accidents was approximately $1,100,000, showing, according to actual figures, an average amount of $72.42 for these two classes of falls, which may properly be called slipping and tripping falls.

Of 100,003 accidents reported by the Industrial Commission of Ohio, covering a period of slightly longer than a year, 10,054 accidents were due to falls, resulting in 139 deaths. These deaths constituted 22.6 per cent. of the number of fatal accidents. Of 96,952 accidents, which resulted in temporary disability, 9,827, or 10.1 per cent., were ascribed to falls. Ten fatal cases were reported due to falling, slipping or stumbling on ordinary surfaces, such as floors. The economic aspect is reflected in the amounts awarded by the commission, as follows:

AWARDS FOR ACCIDENTS RESULTING FROM FALLS.

	Total Award.	*Average Award.*
111 accidents resulting fatally	$284,684.17	$2,564.72
59 accidents resulting in permanent partial disability	37,969.00	643.54
7554 accidents resulting in temporary disability	285,658.00	37.81

Making the total award $608,311.17, or an average award of $78.76 for the 7724 accidents. These figures include falls of all kinds, and the number due to slipping and tripping can only be estimated from other similar statistical reports.

The report of the Industrial Commission of Wisconsin, covering industrial accidents for a period of two and one-half years, shows that of 18,165 accidents, causing disability for more than one week, 2882 were due to falls of persons. On a certain arbitrary basis assumed for estimating economic loss, an amount of $839,700 was placed against the 2882 accidents due to falls. Of this number of falls, 111 were down stairs, two of which resulted fatally; 689 were due to slipping, and 422 due to stumbling.

The report of the Commissioner of Labor and Industry of the State of Pennsylvania shows that 11 per cent. of the accidents in the state of Pennsylvania during 1914 were due to falls. Of 38,126 accidents, those resulting from falling and slipping or tripping on the ground level alone amounted to 2149, which was 51 per cent. of the total number of reported falls, and 5.6 per cent. of the total number of accidents. Of 1005 specific accidents resulting from slipping on the ground level, the loss in time averaged 12 days per accident. The total value of lost time was $31,263.55, a loss of $31.11 per accident, at an average wage of $2.49 per day. A similar report from public service corporations, covering 907 accidents to employes due to falls, caused by slipping on the ground level, shows an average loss of 16 days' time per accident; a total value of lost time of $24,287.95, or $26.78 per accident at a daily wage of $2.39.

The Industrial Accident Board of Massachusetts, in a report covering the year ending June 30, 1915, shows that of 94,597 non-fatal accidents, 8749, or 9.2 per cent., were due to falls. Of 370 fatal accidents, for the same period, 82 were due to falls. Of 249 fatal accidents, due to falls, reported in a three-year period, 10 were falls down stairways and 4 were due to slipping on the level.

While the above data is too incomplete to warrant making definite deductions; yet, it seems to indicate that falls of persons constitute from 10 to 15 per cent. of the accidents to employes of industrial concerns, and that the proportion of these falls directly traceable to slipping and stumbling on the ground level varies greatly, but can be roughly placed at 50 per cent. The average loss in wages, or the compensation allowed per accident, varies from $25.00 to $80.00. These figures are obtained from the industrial world, and cover damages paid without litigation, to employes earning low wages. It may readily be inferred how much more expensive accidents around passenger stations must really be to railroads, involving as they so often do, not only litigation, but the payment of high damages to persons in all walks of life.

Your Committee corresponded with the Claims Departments of many of the large railroads, in an effort to obtain statistics as to the actual causes of accidents in and about stations. Very meager results were obtained, as the records of the Claim Departments are not kept so that statistical data can readily be compiled. The following information, however, may be of interest:

The Santa Fe System, Lines East, for the year ending June 30, 1917, reports 36 accidents to passengers, not including accidents at the large terminal stations where business is handled by separate terminal companies. Nine of these accidents occurred as passengers descended from trains, due to the step boxes turning or being missed. Eight resulted from stumbling over rails or tracks, and the balance from slipping. Four accidents were due to slipping of persons running to catch trains, 3 to slipping on platforms, 5 to slipping on floors and 2 to tripping on stairways.

The Central Railroad of New Jersey, for the year 1916, reports 252 accidents to passengers in and about stations, as follows: 58 per cent., or 145 accidents, to persons boarding or leaving cars; 20 per cent., or

51 accidents, due to car doors closing on hands; 22 per cent., or 56 accidents, from people falling at stations with no train involved. Of the last item, 9 accidents were due to stumbling or tripping over obstructions, or by the collision of persons with baggage trucks; 12 were due to slipping on ice, or particles, on platforms; 24 were due to other tripping—on platforms, rails, etc.; 11 were due to falling or tripping on stairs.

While the above is very incomplete as to accidents to passengers; yet, it is illuminating as to the actual causes of personal injury, and probably may be accepted as fairly representative of the kinds of accidents that occur throughout the country.

Safeguarding against accidents at stations involves not only suitable general arrangements so as to partially or wholly separate traffic and to avoid cross currents of travel, but also the observance of many minor details of construction and maintenance. Slipping, tripping and falling on the level surface of sidewalks, platforms, concourses and ramps will be largely avoided if due consideration be given to the following:

(1) No chance should exist for stumbling over or hitting objects or projections which cannot be easily seen by a person walking in a dense crowd, especially along main lines of travel.

(2) No construction should be used which leaves the slightest projection about the general walking surface to cause slipping and stumbling. To observe this throughout, especially in sidewalk construction, may prevent the use of many commercial devices and call for special construction.

(3) Iron, glass, and other materials which get smooth and slippery with wear, should not be used in large enough areas or units to endanger walking due to slipping.

(4) The character of materials used and the finish of surfaces of floors, platforms and sidewalks should, as far as may be justified, be anti-slipping in their nature. Due consideration should be given to the character of use and to the condition of the surface as affected by weather.

(5) Where rush traffic must be cared for, as in corridors or exits, nothing should be located to engage the attention of the person or cause him to stop or change the direction of his travel. The grouping of stores, or other conveniences either side of main entrances, should be considered a questionable practice from the viewpoint of safety, unless such entrances are far wider than required to handle the people who will use them in rush hours.

Some railroads have abandoned the use of concrete for station platforms, partly on account of the slippery surface. However, concrete is in general use throghout the country, the materials are readily obtainable, and doubtless it will continue to be used in many places for sidewalks and platforms. Your Committee feels warranted, therefore, in offering the following suggestions regarding the use of concrete for such construction:

(1) When constructed, a smooth, troweled finish should not be permitted, but a rough surface obtained.

(2) Some waterproofing substances and other materials, which give a very dense, hard, smooth surface when troweled, or worn, should be avoided, as such sidewalks are exceptionally slippery when wet or slightly coated with mud.

(3) Some material should be used throughout the finishing coat which, under wear of the sidewalk surface, will prove to be harder and more resisting to wear than the other material on the surface, so as to give, in effect, an abrading material.

In some localities, certain small gravels used with sand prove more resisting to wear than the mortar, and furnish a surface which quickly becomes rough, and will even remain so when slightly coated with ice or sleet.

An abrasive material may be added as an ingredient of a sidewalk finish; the one objection being that it may not be so firmly held in the cement or mortar, as to prevent its being kicked out and acting as an abrasive to wear out the surface. This objection applies more particularly to the use of this material in safety treads than in sidewalks. Very good results have been obtained, in several instances, with the following sidewalk finish:

12 parts No. 20 abrasive grit (alundum)
34 parts cement
54 parts sand

For sidewalks on grades, abrasive material, in small blocks, or units, such as carborundum circles and grit, are sometimes used. These are placed with the idea of catching the foot as it slips down the grade. A criticism of some installations is that the abrasive material is so located that the foot can slip between the units. Where the expense is justified, such abrasive units should be so placed that the foot cannot slip more than three or four inches without coming in contact with an abrasive surface.

A floor finish in small tile, mosaic or terrazzo, should not be used for sidewalks or main corridors where, during wet weather, they are liable to be traversed by people with wet or muddy soles on their shoes. Experience shows that the slightest film of grease, or mud, on such surfaces presents a very dangerous condition. This is sometimes guarded against by the use of sawdust. Your Committee recommends no such surface be used on sidewalks or any place about stations except in waiting rooms or other places where it can be maintained in practically a clean condition at all times. Experience shows that most of the soap powders used in cleaning such floors contain an element of grease that clings to the floor surface and is not removed merely by water and rubbing. Cleaning materials of an abrasive nature and with a minimum of soap should be used, so as to leave the floor in a clean non-slippery condition. This matter should receive the attention of those responsible for the maintenance of station floors.

Brick has been largely used for railroad platforms because it usually presents a somewhat rough surface. When covered with frost or a slight coating of ice, the brick platform is, however, very slippery, and some consideration is being given to the use of mastic surfaces for platforms in an effort to find a material which will be reasonably non-slippery under practically all weather conditions.

On sidewalks, a deal of slipping is caused by worn vault light installations and by smooth iron surfaces. The use of smooth glass surfaces in a sidewalk is very objectionable, but, unfortunately, necessary in many cases. Very few building codes limit the size of plain glass or plain iron surfaces in sidewalks, although one or two cities limit the maximum dimensions to about 2¾ in. The combination of a badly worn set of round vault lights with worn and muddy heels in wet weather is such a menace to safe walking, and such an inducement to slipping, that your Committee recommends that where the use of such lights cannot be avoided, that the cement filling between the vault lights be composed of the hardest ingredients that can be obtained locally, combined with an abrasive substance, in an effort to make the cement filling between the lights stand up better under traffic than does that now commonly used.

There appears to be great indifference to the hazard of slipping and tripping on sidewalks due to iron parts, such as covers and frames for coal holes, ash hoists, curbing protection, etc. When originally installed, most all such iron surfaces are checkered, or roughened, to a greater or less degree, but no great importance is attached to the fact that, due to wear, the iron will become perfectly smooth and in both dry and wet weather, present one of the worst causes of slipping. In many cases, it is possible to avoid the use of iron, or to use a ribbed frame which can be filled in with a suitable non-slippery wearing surface. Where the use of iron cannot be avoided, it is still possible to overcome the slippery feature by purchasing iron on the market in which has been imbedded, when cast, a hart abrasive grit. The practice still obtains in some places of using a smooth iron at curbing when equally good protection could be given by a steel plate on edge, or nosing suitably anchored to the sidewalk. Your Committee recommends that the use of ordinary flat surfaces in sidewalk construction be considered to create an objectionable hazard, and that either such iron be furnished with a wearing surface of imbedded grit or else that the area of the surface be reduced to that of narrow lines, so arranged as to provide for the use of a filling or wearing surface of some other material.

Slipping, tripping and falling on stairways may easily have severe or fatal results. The stumbling of a single person on a stairway during a stampede, caused by fire, has often resulted in great loss of life, so that the public has become greatly interested in the matter of safety on stairways, where they form a part of main exits. This interest is reflected in state and city building codes in the matter of stairway construction in factories, school houses and in theaters, or auditoriums, so that these codes now contain the best governmental regulations to safeguard the handling of excited people moving in crowds.

The following extracts from the building code of the state of Ohio is typical of the usual requirements for stairways in theaters and auditoriums:

"No stairway shall be less than three feet six inches (3′ 6″) or more than six (6) feet wide, measuring between the hand rails. * * * Where the seating capacity exceeds the limit for two six (6) foot stairways, wider stairways may be used, providing a substantial center hand rail with newel and angle posts not less than six (6) feet high, dividing the stairways into widths not less than three feet six inches (3′ 6″) and not exceeding six (6) feet wide. Stairways used by the general public shall have a uniform rise of not more than seven (7) inches and a uniform tread of not less than ten and one-half (10½) inches. * * * No riser shall be less than five (5) inches. No stairway or steps that may be used as a means of egress in ascent shall have nosings. No stairway shall have more than sixteen (16) nor less than three (3) risers in any run. No winders shall be used and all nosings shall be straight. Hand rails shall be provided on both sides of all stairways and steps. * * * A uniform width shall be maintained to all stair and stair platforms used by the general public by rounding or beveling the angles and corners. No door shall open directly upon a stairway, but shall open upon a platform, or landing, equal in length to the width of the door. * * * Stair treads shall be either carpeted or be covered with rubber or lead mats, securely fastened to place or the tread shall be formed of a non-slipping surface. * * * To overcome any difference in levels in and between courts, corridors, lobbies, passageways, auditoriums and aisles on the ground floor, gradients shall be employed. Gradients in auditorium aisles shall not exceed one (1) foot in rise to five (5) feet in run, and no other gradient or incline shall exceed one (1) foot in rise to twelve (12) feet in run. Sills at all exits shall be so designed as to be level and flush with the adjacent floors."

Standard regulations regarding stairway construction most generally approved by Casualty Companies and large corporations are those adopted by the Workmen's Compensation Service Bureau, and published in a book "Universal Safety Standards," prepared for the Bureau by Carl M. Hansen, M. E., from which the following is quoted:

"STAIRS."

"Any flight of steps having more than three (3) risers:

"(a) To have approved slip-proof treads in good condition, firmly secured and with no protruding bolts, screws or nails.

"(b) To be free from winders.

"(c) To have landings located twelve (12) feet or less apart measured in a vertical direction, both dimensions of such landings to be equal to or greater than the width of stairways between handrails (or handrail and wall).

"(d) Landings to be level and free from intermediate steps between main up flight and the main down flight.

"(e) All treads to be equal and all risers to be equal in any one flight.

"(f) The sum of one tread and one riser, exclusive of nosing, to be not more than eighteen (18) inches nor less than seventeen (17) inches.

"(g) Angle of stairs with horizontal to be not more than fifty (50) degrees or less than twenty (20) degrees.

"(h) Nosing not to exceed one and one-quarter (1¼) inches.

"(i) To be equipped with permanent and substantial hand rails thirty-six (36) inches in height from center of tread, as follows:

1. On all open sides.
2. On one side of enclosed stairway four (4) feet or less in width.
3. On both sides of enclosed stairway over four (4) feet in width.
4. On both sides and in center of stairway over eight (8) feet in width.

"(j) Handrails to be constructed of pipe, iron work or wood, conforming to standards as specified under "Floor Openings," or of material and construction of equal strength.

"(k) All handrails to have rounded corners and to be smooth and free from splinters."

A few railroad systems have adopted definite, standard practice for stairway construction, the main features of which are also used by many other roads which have not directly formulated their practice.

The following extracts from a committee report of 1914 indicates the present practice of the Pennsylvania Railroad:

"For stairways used by the Traveling Public:

"The sum of two risers and one tread shall be between 25 and 26 in.

"No tread shall exceed 13 in. or be less than 12 in., and no riser shall be more than 6¾ in., nor less than 6 in.

"No corrugated nor ribbed tread over $\frac{1}{16}$-in. in depth shall be used on any stair.

"Non-corrugated, anti-slip treads or lead and alundum, or carborundum, iron and carborundum, or alundum, or concrete and alundum or carborundum are recommended for any width of not less than 8 in. on tread, including nosing.

"Nosings having a projection not exceeding 1 in. are recommended for use on treads.

"All measurements are to be from top to top of treads and face to face of risers.

"All stairways to have handrails at each side. Top of handrail to be 3 ft. above top of tread, measured vertically at nosing.

"All stairways requiring more than 18 risers should have a landing 4 ft. wide, and in general, the single flights should be kept down to 10 or 12 risers where possible.

"The height of risers and width of treads for stairways used by the Traveling Public shall be the same for all such stairways throughout in any one building.

"For stairways in office buildings and in places used jointly by employes and the General Public:

"The sum of two risers and one tread shall be between 24 and 25 in.

"No riser to exceed 8 in. or be less than 7 in.

"No tread to exceed 11 in. or be less than 10 in.

"All stairways to have handrails at sides. Top of handrail to be 3 ft. above top of tread measured vertically at nosing.

"Non-corrugated, anti-slip treads of lead and alundum or carborundum, iron and alundum or carborundum, or concrete and alundum or carborundum are recommended for a width of not less than 8 in. on tread, including nosing.

"All stairways requiring more than 18 risers should have a landing 4 ft. wide, and in general, the single flights should be kept down to 10 or 12 risers where possible.

> "The height of risers and width of treads for stairways in office buildings and in places used jointly by employes and the General Public shall be the same for all such stairways throughout in any one building."

Your Committee, after considering building codes, regulations adopted as "Safety First" measures by industrial corporations and present railroad practice, makes certain recommendations given in the "Conclusions" of this report, covering the construction of stairways, as far as the feature of safety provisions is concerned.

These recommendations suggest that the rush capacity of stairways and passageways be determined by a local study of character of traffic handled and rate of movement rather than by any general rules or formulae. This was done in connection with the construction of the Hudson Terminal Building, New York, and a discussion of the results appears in the American Architect of January 19, 1910, in an article by J. Vipond Davies and J. H. Wells, from which the following is quoted. Referring to the Hudson Terminal Building:

"To ascertain the necessities in respect of stairs and passages, count of actual movement of traffic at congested points in New York was made, notably at the Brooklyn Bridge. In a straight passage of ample width, the "rush hour" New York crowd moves at the rate of 300 ft. per minute, walking with a step averaging 30 in. There is only a small reduction in this speed on ramps of, say, not over 10 per cent. grade. At this rate, each person averages about 10 sq. ft. occupied and the movement discharges about 30 persons per foot of width of passage. If the passage way becomes too congested, the space occupied per person reduces, and the speed of movement also reduces, but the number discharged remains about the same, 30 per minute. Any contrary movement in a broad passage reduces the movement rather more than the relative space occupied in multiples of, say, 30 in. per person, but in narrow passages the relative reduction is much greater, notwithstanding that persons crowd into smaller space, not over 24 in. width.

"A crowd moving freely upwards on stairs takes about the same number of steps per minute, say, 120, but advances only about 12 in. horizontally instead of 30 in. Upstairs movement is much more dense than downstairs, but correspondingly slower. We have counted discharge on stairs of 24 persons per foot of width per minute moving upwards, but never more than 18 per foot of width moving downwards. There does not appear much difference in discharging rate on stairs above 4 ft. wide if the movement is all in one direction, but stairs of all widths (particularly below 8 ft. wide) are seriously impeded by any contrary movement, even when only four or five persons are moving in the direction reverse to the heavy traffic. Generally, for stairs above 4-ft. width, all movements in one direction indicates:

"Upwards—Maximum, 20 persons per foot of width of stairs per minute.
Average for ordinary free moving crowds, 15 per minute.
"Downwards—Maximum, 18 per foot of width of stairs per minute.
Average for ordinary free moving crowds, 13 per minute."

All main stairways should be provided with safety treads, of which there are many different makes on the market, most of which have good and bad features. An attempt to discuss the relative merits of these treads is inadvisable, as for the most part they are patented articles, and there is not enough statistical data obtainable to conclusively support comparative statements.

Patented treads may be said to be of the following four general types:

(1) Sheet metal, pressed up into diamond or other shapes, with sharp edges, either with or without perforations. Such treads are not ornamental, are generally efficient when new, are claimed to be cheaper than some other forms; and, undoubtedly, better fill a need in the industrial world than in connection with passenger stations.

(2) Tread bases with a plain, flat top, in the surface of which has been incorporated an anti-slipping coating, or material. The simplest article of this nature is the wooden stair tread, covered with sand-covered or other prepared roofing paper. A much used tread, adaptable to all shapes and needs that may arise, consists of a cast iron case, in the surface of which, while hot, there is imbedded an abrasive grit made from caborundum. This tread is not ornamental, but very efficient. It wears well, and retains its anti-slipping nature, but should be renewed before the abrasive material entirely wears away at any point. Another make of tread coats a base with a lead cover, or surface, in which carborundum or other abrasive grit is used.

(3) Metal bases of steel, or brass, with an upper surface so formed by corrugations, or projections, as to hold wearing surfaces of lead or carborundum. Such treads are ornamental, widely known and in common use.

(4) Tread bases consisting of a filling, or composition combined with abrasive units in a smooth, flat surface. The abrasive units are sometimes held in place by a metal sheet, or frame, which is imbedded in the mortar, or other material composing the major part of the tread. The value of this kind of tread depends upon the amount and position of the abrasive units used, and the action of the combination under wear, particularly as to the hold on abrasive material as the tread becomes badly worn.

Between competitors there is considerable argument regarding the use of corrugations running parallel with the edge of the step. It is claimed that as persons are descending stairs they are apt to catch their heels in the corrugations and be thrown; whereas, the counter claim is made that a slightly corrugated surface will catch a match, or any other small particle which might otherwise roll under the foot and induce slipping. The normal position of the foot in descending stairs is at a slight angle with the horizontal, giving a line of contact between the sole of the shoe and the stair tread. This contact should be anti-slipping in nature if possible, so that the outer strip of metal holding the abrasive units should either be abrasive itself in nature or in construction it should be as narrow as the needed mechanical strength will allow, and should wear down equally as fast as the abrasive units held by it. When safety treads are not renewed when worn out, they constitute a menace, as often the front, or outer, metal edge will separate from the balance of the tread and catch heels. When treads are exposed to the weather, they often give trouble from the cracking and breaking of carborundum inserts, the lifting action of front on inserts and from rust of iron or steel. Many treads which are quite efficient in dry weather are slippery in wet weather or when slightly coated with snow or ice.

It might seem that the ideal material for a tread would be a material with which an abrasive material could be mixed, and which could be poured in place behind a thin, outer retaining strip of metal; thus giving a smooth surface and one that would be equally anti-slipping when new or considerably worn. Experience shows that even if the metal strip could be so composed as to wear away equally as fast as the filling that such construction would not remove the slipping hazard. Those with experience in such materials uniformly believe that worn units induce slipping, and that the only proper construction is one that permits removal of worn safety treads and restoration of a step to first-class condition.

The importance of guarding against slipping, tripping and falling, and the economical value of provisions to insure safe walking, is due not so much to the great risk of accidents to any one person as it is to the fact that this relatively small risk is incurred by millions of persons walking daily in and about passenger stations. The preventives and safeguarding provisions are not costly. They merely require proper thought and consideration at the time plans and arrangements are adopted. The public is fast being educated in safety features in industrial buildings, theaters and other places of public assemblage, and may rightfully expect that all provisions to safeguard walking, which experience has shown to be needed or helpful, shall be found in use in passenger stations throughout this country.

CONCLUSIONS.

In connection with the construction of new passenger stations and the maintenance and alteration of old stations, special study and consideration should be given to provisions for the safety of pedestrians in an effort to remove, as far as possible, all risks of personal injury, particularly from slipping, stumbling and falling. The actual risks and their relative economic importance are revealed by experience of railroads handling rush crowds, the statistics of insurance and compensation bureaus, and are also reflected by state and city building codes, relative to construction of factories, schools, auditoriums, etc.

Personal injury in and about passenger stations results either from colliding or slipping and stumbling.

Where crowds are handled, injury from colliding of persons with trains or trucks should be guarded against by arrangements to prevent passengers crossing tracks, to eliminate or reduce to a minimum the trucking of baggage, mail, and express on main passenger platforms, and to guard people waiting on platforms at way stations, by the use of dead lines or station fences.

Colliding of persons with hand baggage and each other should be prevented or largely avoided by proper general arrangements of depots, particularly in the matter of location and proportions of passageways and stairways, with the primary object of separating different classes, or lines, of traffic as much as may be practicable, and of maintaining any certain line of traffic free from interference and points of congestion. Particular attention should be given to the location of ticket offices, information bureaus, check rooms, entrances to minor waiting rooms, and similar conveniences, and a study made of possible interference with main lines of rush travel. Concourses should be provided with as many main exits as practicable to prevent unnecessary travel through main waiting room—union depots recently built, showing that often 70 per cent. of the traffic can be thus handled.

Personal injury from slipping, stumbling and falling should be guarded against by choice of finish and wearing surfaces for floors and platforms, by avoidance of many details in common use which induce stumbling and slipping, by proper construction of ramps and stairways, including the use of safety treads on all main stairways, and by proper standards of maintenance, both as to condition of use and time of renewal or repair.

The construction of stairways in passenger stations should conform as to safety features to the "Recommendations" given below.

No plans for extensive alteration of existing passenger depots, or general layouts for new stations, should be approved without a critical examination or study being made of the traffic movement in rush hours, and no details of construction should be used affecting stairways and surfaces on which passengers walk without careful consideration be given with a view to avoid or reduce as much as may be possible the risk of personal injury to passengers in and about stations.

RECOMMENDATIONS COVERING SAFETY PROVISIONS IN THE CONSTRUCTION OF STAIRWAYS FOR PASSENGER STATIONS.

General.

These recommendations include the main requirements of building codes of a number of representative large cities, but should be used with due regard to local city and state regulations. Provisions as to strength of construction and fireproof features are not included.

Avoid steps and stairways where inclines and ramps can be satisfactorily used instead. Avoid any combination of sloping surfaces and steps.

Consider both the general design and details of stairway construction with a view of handling crowds of people with the individuals moving in parallel lines with ease and with safety, against slipping and falling, keeping such movement free from interference by other lines of travel.

General Location.

Place important stairways conspicuously in the main line of travel, keeping such travel in straight lines where possible. Arrange so that crowds at the head and foot of stairways can naturally assemble and disperse, with a minimum amount of confusion and cross-currents of walking. To this end, provide at the top and bottom of stairways, where possible, corridors or vestibules, using the same width as for the stairway. Such corridors should open directly into the room served without any funnel-shaped entrances, and with plenty of room for quick distribution.

Locate minor stairways away from regular lines of travel, and avoid combinations of service or minor stairways, with main stairways.

Consider possible lighting arrangements, particularly from natural light, avoiding locations where stairways will be poorly lighted in cloudy weather or where they will appear dark to a person entering them from bright sunlight.

Type.

For main stairways, use a straight run of steps and landings wherever architecturally possible. Where turns cannot be avoided, provide landings and, if possible, restrict the turn to ninety degrees.

Width.

Proportion the width according to the character of traffic handled, the extent to which hand baggage will be carried, and the maximum stairway capacity desired during rush hours. Be guided by experience with local requirements rather than by thumb rules, bearing in mind that main stairways should be maintained wide enough so as not to check the movement of crowds, and that the width of minor stairways should often be determined by the rate at which people may continue to move away from them. (See body of report for certain data obtained in connection with construction of Hudson Terminal Building, New York).

Bevel, or round, landings to maintain a constant width, and keep people moving in concentric, or parallel lines.

Where two stairways unite at a landing and form a single stairway, make the width of the latter equal to the combined widths of the other two.

For minor and service stairways, use no width less than 3 ft. 0 in. between hand rails.

Pitch and Landings.

The pitch of stairways, i. e., the inclination as determined by the dimensions of treads and risers, and the frequency and proportion of landings, should be such that stairways may be ascended with ease, and as nearly as may be with a free natural walking step. The continuous upward lifting of the body, for anyone not accustomed to such exercise, and particularly for fleshy people, those with weak hearts, or anyone in poor health, is a great exertion. Landings break the continuity of this exertion, and offer a needed resting place for the weak. To fix pitch and landings properly, the following should be approximately observed:

Provide treads not over 13 in. nor less than 11 in. in width, and risers not over 7 in. nor less than 6 in. in height; and make the sum of two risers and one tread be between 25 in. and 26 in. The width of treads should be taken as the horizontal distance face to face of risers.

Where stairways require more than 16 risers, provide intermediate landings, keeping the length of single flights as near to 10 or 12 risers as may be possible. Use no steps with less than three risers.

Where feasible, provide the same height of risers and width of treads for all stairways used by the traveling public in any one building. Always make risers and stringers of closed construction.

Make the width of landings in the direction of travel not less than four feet.

Avoid, if possible, all minor entrances on landings or at the top or bottom of main stairways. If this cannot be done, provide suitable length of landings, so that doors can be opened and used freely by any minor class of traffic without, in anywise, causing interference with travel at the main stairway.

Railings.

Provide hand rails on both sides of all stairways and center rails on stairways eight feet wide, and additional rails to keep the distance between adjacent hand rails not less than 3 ft. 0 in. nor more than 6 ft. 0 in. Where intermediate hand rails are used, a double hand rail is recommended. Place center line of hand rails at least 5 in. from face of sidewalls, or 8 in. center to center for intermediate hand rails. Make section of hand rail rigid to give uninterrupted travel for a secure grip. Provide a hand rail without sharp drops or raises, and extend it beyond the last riser, and turn it downward, so that it offers no entanglement for clothes or baggage. Curve hand rails at all bends on landings. Provide such balustrades and hand rails as will prevent small children from falling or getting through them. In this connection, consider the use of curb to divide stairs under the center hand rails. Place top of hand rail 34 in. above tread, measured on line of face of riser. On the open side of stairways, provide barriers at least 42 in. high, to guard against accidental falls of persons over balustrade. At intermediate hand rails, provide newels not less than 6 ft. high, and secure the rails to them without encroaching on hand clearance. Provide newels which will not present sharp edges and corners.

Drainage.

Obtain necessary drainage at the ends of the treads, and not by sloping the surface in line of travel.

Treads.

Where used, nosings on treads should be limited to a projection of 1 in.

Provide approved safety treads on all main stairways, using a renewable type securely fastened. Make length of safety tread 4 to 6 in. shorter than that of the stair tread, and use a width of safety tread of from 5 in. to 8 in. Place the surface of the safety tread flush with surface of the balance of the stair tread. Consider means, such as color schemes, which used in connection with safety treads, will clearly indicate the location of the steps, particularly the outer edge or nosing.

The use of wide safety treads, particularly those covering the entire width of the step, are of questionable necessity and value, as they present a uniform appearance for the entire flight of steps, and make it difficult for people to clearly see where they are stepping.

Outside Stairways.

Where feasible, enclose, or roof over, all outside stairways not only to keep off sleet and snow, but also to prevent a slippery condition, due to rain and mud. Do not provide open risers. In choice of safety treads for outside stairways, consider means which will have to be used during winter weather to maintain surface of steps in good condition.

Signs.

Place no signs, mirrors, or other objects of interest where they will attract the attention of persons using stairways, except such signs as are necessary to direct travel.

Lighting.

In making lighting arrangements, consider that many people with poor eyes cannot, at best, see very clearly in descending stairways, particularly when the appearance of treads is uniform throughout. Provide ample natural and artificial light, avoiding direct light and shadows, and making certain that lights from adjacent rooms do not shine directly into the eyes of people using stairways.

Maintenance.

In the choice of materials and arrangements, consider the maintenance conditions that will exist in daily use, particuarly those in wet and stormy weather just before stairways are cleaned, and also give consideration to that poorest condition of safety treads and other parts which will exist just before renewal is required and made.

Appendix C.

DESIGN AND MERITS OF HIGH AND LOW PLATFORMS AT PASSENGER STATIONS.

While very few railroads in this country have adopted platforms level with the car floors, they have always been the standard in use in Great Britain.

Platforms are built of either wood, concrete, steel, or a combination of these materials. At important points, where traffic is heavy, they should be equipped with either an umbrella or butterfly shed.

If the adjacent tracks are to be used for both passenger and freight trains, careful consideration should be given to clearance. There are some raised platforms where both passenger and freight trains use the adjacent tracks where the distance from the center of the track and face of platform is 5 ft. 4 in.

There are platforms fitted with mechanical extensions, moving out until they practically touch the side of the car, so that there is no space between the side of the car and the platform. These extensions are moved back before the train is started.

It is recommended that the following be taken into consideration in considering the adoption of high platforms:

First—Facility and rapidity with which trains may be loaded or unloaded.

Second—The prevention of the public crossing the track.

Third—In stations below the street level, a saving of about 3 ft. in the vertical height to be traveled by the passengers.

Fourth—They form a convenient place for the housing of ducts, cables, signal equipment and sometimes elevator machinery.

They have certain disadvantages when used in conjunction with our present system of terminal operation:

First—(Most important)—The cost of changing passenger equipment to serve both high and low platforms.

Second—The difficulty of trucking across the tracks.

Third—The necessity for special form of baggage truck having a low floor.

Fourth—The disadvantage of placing a switch within the limits of the platform.

The Committee recommends that the Association recommend to the Master Car Builders Association that all cars in future be so constructed that they will fit either high or low platforms.

American Railway Engineering Association

VOL. 19, No. 202 . . . . DECEMBER, 1917.

BOOK REVIEW.

BUSINESS LAW FOR ENGINEERS, by C. Frank Allen, formerly Professor of Railroad Engineering, Massachusetts Institute of Technology. New York and London. McGraw-Hill Book Co., Inc., cloth, 6x9 in., pp. 430. Price, $3.00 net.

In the preface the author states: "The purpose of this book is not to make 'every man his own lawyer,' but rather to give the Engineer a sufficient understanding of important fundamental features of law, so that he may have some idea of when or how to act, himself, and when to seek expert advice, as well as to enlarge his horizon and perhaps encourage him to further study of law." That Professor Allen has accomplished the task that he set for himself is evident.

The book is divided into two parts: Part I, Elements of Law for Engineers, and Part II, Contract Letting. The subjects covered in Part I are Evidence; Contracts; Torts; Equity; Real Property; Corporations; Agency, Master and Servant; Sales; Negotiable Instruments; Railroads, and the Engineer's Legal Relations to Others. The subjects covered in Part II are Advertisement; Information for Bidders; Proposal; Uniform Contract Forms; Bond, and Specifications.

The book is clearly written in a pleasing style and gives evidence of careful writing on the part of the author. The chapter on Evidence is of especial value and should be read and studied by every Engineer. The chapter on Negotiable Instruments is very complete and in the opinion of the reviewer gives the best treatment of the subject outside of special treatises.

The treatment of contract letting in Part II is especially satisfactory for the practicing Engineer, although it might be criticized as being too extensive for use as a textbook. The Uniform Contract Form as adopted by the American Railway Engineering Association is given, and other contract forms are given for comparison.

As a textbook for engineering students the book falls short of the requirements as given in many engineering schools in that it omits the subjects of Insurance, Irrigation Law, Franchises, Valuation of Public Utilities, and does not give adequate attention to easements other than as applied to railroads; no practice is given in the very necessary art of contract writing, and specifications are merely mentioned.

The book is well printed and bound and is a credit to both the author and the publisher. For the Engineer it leaves little to be desired for the subjects treated, while with the inclusion of the subjects noted in the beginning of the review together with some condensations of Part II, Contract Letting, the book would admirably fill the needs of technical schools.

M. S. KETCHUM.

ENLISTMENT IN THE 33RD ENGINEERS.

GENERAL CONSTRUCTION REGIMENT—IMMEDIATE SERVICE ABROAD.

Request has been made that publicity be given to the following notice, which is self-explanatory:

There is now forming at Camp Devens, Ayer, Mass., under the command of Colonel Mark Brooke, C. E., U. S. A., a regiment of engineers for general construction work in France. In it are offered the greatest opportunities of any unit thus far organized for all classes of labor, skilled and unskilled, who are qualified for this kind of work. Bridge, building and form carpenters, structural steel men, reinforcing steel setters, engineers, firemen, mechanics, machinists, steam fitters, miners, blacksmiths, riggers and derrick men, pile driver operators, brick and stone masons, concrete men, construction superintendents and foremen, civil and mechanical engineers, clerks, stenographers, timekeepers, paymasters, storekeepers and supply men, in fact, every kind and class of worker on a building or construction job are needed. Men showing ability and qualifications will have an opportunity to quickly become non-commissioned officers, ranking as high as master engineer, senior grade, the highest in the service. As soon as the regiment is filled and the equipment shipped, the 33rd will leave for "over there."

Men of draft age may join by applying by mail to Headquarters 33rd Engineers, Camp Devens, Ayer, Mass. State age, address, occupation, draft status and number, name and number of local board and signify desire to volunteer for immediate service in this regiment.

Men not in the draft, between 31 and 41, may enlist at the nearest U. S. Army Recruiting Station, specifying that they are enlisting for service with the 33rd ENGINEERS.

MEN IN THE DRAFT CAN VOLUNTEER FOR THE 33RD.

RECRUITING MEN FOR TRENCH WARFARE SECTION.

ENGINEERING BUREAU—WAR DEPARTMENT.

The Trench Warfare Section of the Ordnance Department desires to get in touch with young men of technical training who can become candidates for commissions in the Ordnance Officers' Reserve Corps.

The matter of gathering this information has been facilitated by the Intercollegiate Intelligence Bureau, which has appointed a representative in each University. It is thought, however, that this work could be advanced by asking the various technical and engineering societies throughout the country to appoint in each society a representative who will bring this matter to the attention of the members and forward their applications, together with a letter of recommendation from himself.

We are in particular need of young men over draft age or in deferred draft classifications, who are physically sound, whose earning capacity is at least $1,700 a year, who have good characters, some business experience, university training and some technical skill—obtained either at school or afterward through business experience and practical shop work.

We have a particularly desirable opportunity for approximately one hundred officers who will be used for instruction purposes in demonstrating to troops the use of grenades, trench mortars, drop bombs and other trench warfare material. These men will probably have an opportunity to go to France. They should possess the general qualifications outlined in this letter, and in addition should be capable of teaching clearly the use of mechanical devices to officers and enlisted men. While they are expected to be instructors, and good instructors, it is contemplated that they shall conform to the type represented by active all-around line officers rather than that represented by officers engaged in research or purely administrative work. A two months' course of instruction will be conducted here for those selected, which will include practical instruction in trench warfare material, some scientific work at the American University, proving ground demonstration, a text-book reading program, and some lectures and instruction on the general duties and deportment of officers, including extracts from Army Regulations, the Manual of Courts-Martial, Field Service Regulations, military courtesy and military correspondence forms. As these officers will be selected in classes of fifty, and as the first class should be ready to begin work by March 1, it is desirable that applications should be forwarded at once in order that they may be considered at this office at as early a date as possible.

If notified to come to Washington, it will be necessary for these men to interview Capt. Hudson Millar, 1800 Virginia Ave., Washington, D. C. They must bring three original letters of recommendation from American citizens, and should be prepared to stay in Washington at least three days. They are specifically advised that the trip will be made at their own expense and that no assurance can be given them that their application will be favorably considered.

Application blank for commission in Ordnance O. R. C. is given below, a supply of which will be forwarded upon receipt of reply.

APPLICATION FOR EXAMINATION FOR COMMISSION IN ORDNANCE OFFICERS' RESERVE CORPS.

(Under Sec. 37, act June 3, 1916.)

.........................., 19..

The Chief of Ordnance, U. S. Army,
War Department,
Washington, D. C.

Sir: I have the honor to apply for examination for a commission as[1] ....of Ordnance, in the Officers' Reserve Corps, organized under the authority of Congress.

My military experience has been: Years.......... Organization and Branch[2] .... Grade.........................

My education has been: Years............ University or College .... Graduated.............. Degree...............
(Name and location.) (Year.)

My business experience has been:
Period.......... Capacity.................... Firm.................
(From—to.) (Name and address.)

[1]Insert grade, first lieutenant, captain, or major.

[2]Insert service in Regular Army of the United States, or Volunteer forces of the United States, or National Guard of any State, Territory, or District of Columbia; also state in what capacity.

My present business or profession is:
Capacity............. Firm............... Salary per Year...........
(Name and address.)

I am a member in good standing in the following engineering societies:[1] ....

I inclose at least three original letters of recommendation, from citizens who know me, testifying to my character, standing, and professional or business experience.

I was born (Month) ...., (Day) ...., (Year), 18....,
at (Town) ...., (State) ...., (Country) ....,
and am[2] ....a citizen of the United States.

Respectfully,

....
(Name in full.)

P. O. address is ....
Examination is desired before Board in session at..................
If commissioned, service is desired at ....
The correctness of the statement above made was sworn to and subscribed before me this............day of...................., 19....

[3]....................................[SEAL.]

....

---

[1]If a member of an engineering society, state society and grade of membership.

[2]Insert "not" if in accordance with fact.

[3]Oath to be taken before, and signature to be made by, officer authorized by law to administer oaths, and must bear official seal.

BULLETIN

OF THE

American Railway Engineering Association

Vol. 19. No. 203 . . . . JANUARY, 1918

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W. D. PENCE, *Editor*.
Chicago, Ill.

E. H. FRITCH, *Secretary*,
910 Michigan Avenue,
Chicago, Ill.

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American Railway Engineering Association

VOL. 19, No. 203 . . . . JANUARY, 1918

NINETEENTH ANNUAL CONVENTION

March 19, 20, and 21, 1918

To the Members of the Association:

The Nineteenth Annual Convention of the American Railway Engineering Association will be held at the Congress Hotel, Chicago, March 19, 20 and 21, 1918, for the transaction of such business as may come before the meeting.

REASONS WHY MEMBERS SHOULD ATTEND.

The present railway conditions, regardless of the causes or reasons which brought them about, now that the Government has taken charge, makes it incumbent upon us as an Association and as individuals to co-operate with the Government and our Executive Officers to devise ways and means of solving present problems and bettering conditions.

While a journey to Chicago for this purpose will involve a certain portion of your time, it is confidently believed that the time will be well spent and more than repaid by the benefit to be derived from contact with men from all sections of the North American Continent, all dealing more or less with problems similar to your own.

PROGRAM.

The Program to be arranged will take cognizance of the changed conditions of the present time in the railway world, more particularly with reference to war emergency yard improvements to relieve the freight congestion; ways and means for overcoming or meeting the shortage of material and labor; devising new ways of labor-saving in maintenance work; reclamation and utilization of scrap material; substitution of other materials for wood and steel; conservation of resources; discovering, if possible, new sources of economy, etc., etc.

WRITTEN DISCUSSIONS.

If any member finds it impracticable to attend the convention, he may still give us the benefit of his views and advice by means of Written Discussion. Such discussions are desired and welcomed, and will materially add to the interest and value of the meeting.

Members are therefore earnestly urged to make their plans to attend the Nineteenth Annual Convention of the American Railway Engineering Association, to the end that we may give the best that is in us towards "WINNING THE WAR."

Respectfully,
JOHN G. SULLIVAN, President.

E. H. FRITCH, Secretary.

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REPORT OF COMMITTEE XXI—ON ECONOMICS OF RAILWAY OPERATION.

F. W. GREEN, *Chairman;*	V. K. HENDRICKS, *Vice-Chairman;*
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PAUL M. LABACH,	G. S. WAID,
FRANK LEE,	C. C. WILLIAMS,
J. DEN. MACOMB, JR.	*Committee.*

To the American Railway Engineering Association:

Subsequent to the 1917 Convention, the Board of Direction created this new Committee on Economics of Railway Operation, to which it assigned the following subject:

(1) Study the relations between railway operation and the location, construction and maintenance of railways, and report on the possible scope and field of action which should be assigned to the Committee on Economics of Railway Operation, and make such progress reports as are possible, in the order of relative importance.

COMMITTEE MEETINGS.

The initial meeting of the Committee was held at Chicago on August 29, 1917, thirteen members being present. The second meeting was held at Chicago on January 9, 1918, six members being in attendance.

On account of the absence of the Chairman of the Committee, Captain F. W. Green, on military service in France, the Vice-Chairman, Mr. V. K. Hendricks, has acted as Chairman.

ORGANIZATION OF COMMITTEE.

The Constitution of this Association says that the object of the Association is "The advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways." The Classification of Accounts of the Interstate Commerce Commission uses the word "Operation" in a broader sense, to include Maintenance (of Way and Structures and of Equipment) as well as "Transportation." Your Committee feels that its function should be the consideration of matters coming within the classification of "Transportation" together with such other matters as affect Transportation costs, or as are affected by Transportation methods. For instance, economics due to water treatment, which affects Transportation expense, would involve a consideration of the maintenance and operating costs of water softening plants, etc.; this Committee could use maintenance data secured from other committees in such cases, in so far as possible. On the other hand, the matter of treating ties is one which does not affect any transportation costs, and should not come within the province of this Committee. The subsequent use of the word "Operation" in this report is on the basis of this interpretation of the Committee's duties.

The work of both the Committee on Economics of Railway Location and this Committee is dependent upon operating costs, and the field of these committees overlaps to a great extent. The scope of the Committee on Location has been very broad, and it would seem that these two committees could advantageously study some matters of operation jointly, especially those in regard to the determination of cost data, and the arbitrary dividing line between the two should be settled by agreement or by the Board of Direction. Some subjects coming within the province of the Committee on Economics of Operation, such as the economics in operation to be derived through construction of additional main tracks, the installation of automatic signals and interlocking plants, the treatment of water, etc., do not come directly within what has been considered as the realm of the Committee on Economics of Railway Location. On the other hand, questions of changes in alinement or grade reduction should be considered as within the field of the Committee on Location.

At the initial meeting of the Committee, it was decided to be the sense of the Committee that its scope or field include all matters affecting the operation of a railroad; but that for the present the Committee confine its efforts to developing economy of operation of existing physical plants, including such additions as may be necessary for economical operation, but not including changes in alinement or grade reduction; that its efforts may be extended, from time to time, as the necessity or desirability arises; that as an essential preliminary it proposes to make an analysis of operating costs, as conclusions and rules cannot be arrived at without analysis of costs and the effect of capital expenditures.

Your Committee fully realizes that the above is a very ambitious program and that the determination of unit costs in a comprehensive manner will require a number of years of investigation, and much expense; but this matter should be given first consideration. Your Committee feels that it can be of some immediate benefit by summarizing in the best manner possible at this time such data regarding unit costs and other operating matters as mav be available from various sources.

There have been some very thorough investigations of operating costs recently by railroads for their own purposes and for the defense of rate cases, some of the results of which would be of considerable value, and it would seem that this Committee should collect this data for analysis, and present to the Association such results as are found to be of value.

The summarizing of data on various subjects and working out of concrete problems will not only place available data in better form for ready reference by the Association, but will also help to determine the needs for future development of the subject. Some of the items that can be dwelt upon to good advantage are as follows:

Economical speed of trains.
Additional main tracks.
Economic lengths of operating districts.
Economic lengths and spacing of passing tracks.
Increase in power.
Train loading.
Water treatment.
Increase in car loading.
Automatic signals.
More economical handling of locomotive fuel.
Improved terminal facilities.
A more liberal application of lubrication of cars.

Four Sub-Committees were appointed at the first meeting, as follows:

Sub-Committee (1)—Maintenance of Way:
S. S. Roberts, Chairman; Frank Lee, C. E. Denney, E. F. Robinson, C. M. Himmelberger, W. J. Jenks.

Sub-Committee (2)—Maintenance of Equipment:
Prof. Edw. C. Schmidt, Chairman; M. V. Hynes, Acting Chairman; G. S. Waid, Ralph Budd, U. E. Gillen, J. M. Egan.

Sub-Committee (3)—Transportation:
Jos. Mullen, Chairman; G. D. Brooke, Mott Sawyer, L. C. Fritch, R. J. Parker, Paul M. LaBach, L. S. Rose.

Sub-Committee (4)—Bibliography:
Dean Wm. G. Raymond, Chairman; Prof. H. E. Riggs, Prof. C. C. Williams, J. E. Teal, Maurice Coburn, J. deN. Macomb, Jr.

The Sub-Committee on Maintenance of Equipment and the Sub-Committee on Transportation are not prepared to submit a report at this time.

MAINTENANCE OF WAY AND STRUCTURES.

At the first meeting of the whole Committee, the term "Operation" was interpreted to include Maintenance in accordance with the "Classification of Operating Revenues and Operating Expenses of Steam Railroads," as issued by the Interstate Commerce Commission, and the Sub-Committee was instructed to review that classification and to state the primary elements which affect the costs under each heading. The Sub-Committee did this and its report therefore indicates a program somewhat beyond the field of this Committee as outlined herein above.

The report may be of value, however, as an indication of how such a problem may be attacked and its principal features are therefore presented herewith. Investigation along the lines proposed could be carried out to advantage and, by a process of elimination, good results could be obtained; but the Committee is now of the opinion that its efforts should be confined within the limits prescribed under "Organization" in this report.

Conclusions and recommendations on economics cannot be made in advance of a knowledge of costs and their variation with changing conditions. These variations cannot be known until the elements of cost are known, separated, analyzed, and co-ordinated into a total.

Among the natural elements which influence cost are the following:

1. The physical characteristics of the territory through which the road is constructed.
2. The physical characteristics of the road itself.
3. The character of the traffic handled over the road.
4. The density of this traffic.
5. The speed at which this traffic is moved.

The conclusions of this Sub-Committee must be based largely upon the findings of the other Committees of the Association, and it proposes to study and to co-ordinate, as far as it may, the pertinent recommendations of these Committees, and suggests that all railway structures, in which it includes roadbed, ballast, ties, rails, etc., etc., be divided into groups, comprising:

1. Those under similar characteristics of territory.
2. Those under similar characteristics of road itself.
3. Those of similar form or design.
4. Those of similar materials.
5. Those under similar duty, i. e., under like traffic conditions.

The cost of construction, the cost of repairs, period of usefulness, and the cost of renewals must be known or ascertained.

With proper analyses under such divisions, it should be possible eventually to make reasonably reliable recommendations for economics in operation as affected by maintenance of way and structures.

BIBLIOGRAPHY.

A Bibliography, prepared by the Library Service Bureau of the United Engineering Society and covering twelve subjects under eight headings, is presented as an Appendix to this report.

Reference is here made to the Bibliography of grade separation presented in the Proceedings of this Association for 1908 and 1909 by the Committee on Roadway.

It is proposed to keep these bibliographies up to date, and other subjects will be searched as may seem desirable from time to time.

RECOMMENDATIONS FOR FUTURE WORK.

Your Committee recommends that the following topics be assigned for the ensuing year:

1. Collect data on operation costs from rate case investigations and any other available sources, and report on the additional investigations necessary to a complete analysis of operation costs. The Committee on Economics of Railway Location should be conferred with by this Committee.

2. Effect of variation in the speed of trains on costs of operation and maintenance.

3. Effect of the construction of additional main tracks on costs of operation and maintenance.

4. Economic length of operating districts.

5. Continue work on Bibliography.

Respectfully submitted,

THE COMMITTEE ON ECONOMICS OF RAILWAY OPERATION.

Appendix A.

BIBLIOGRAPHY ON ECONOMICS OF RAILWAY OPERATION.

Economy of Double Track on Railroads and the Relation of Power Equipment to Grade and Double Tracking.

1891—Wellington, Arthur M.

Economic theory of the location of railways, p. 675. 1891. N. Y. Wiley.

Expedients for reducing the rate and cost of high grades.

1898—Armstrong, Albert H.

Some phases of the rapid transit problem. 1898. (In Trans. Am. Inst. of Elec. Engrs., v. 15, p. 377.)

Tractive effort in relation to grade, in electric trains.

1902—Limits of capacity of single track. 1902. (In Railway & Engng. Rev., v. 42, p. 182-189.)

Symposium on the question.

1905—Double tracking of railways. (Editorial.) 1905. (In Engng. News, v. 54, p. 276.)

Advocates double tracks for railroads on account of higher degree of safety and traffic being handled to better advantage.

Double tracking of railways. 1905. (In Engng. News, v. 54, p. 524.)

Data on the traffic conditions in regard to double-tracking of railways and estimates of cost of single and double track.

Some practical points in the double tracking of railways. 1905. (In Engng. News, v. 54, p. 265.)

Discusses the economic side.

1907—Double-tracking and yard improvements to facilitate freight traffic on railways. 1907. (In Engng. News, v. 57, p. 382.)

Investigation of the question of extra facilities of double track over single track lines.

Camp, W. M.

Notes on track construction and maintenance, pp. 623, 1187. 1903. Chicago.

The author.

Contains an abstract from symposium in Railway & Engng. Review.

1908—Raymond, William G.

Elements of railroad engineering, p. 360. 1908. N. Y. Wiley.

Shows estimated probable cost of doubling the engine tonnage to handle the same traffic upon one mile of railroad due solely to an increase in the maximum or ruling gradient.

1908—Tratman, E. E. Russell.

Railway track and track work, pp. 8, 452. 1908. N. Y. Engineering News. Contains one page on double tracking of railways.

1910—Engineering construction on the Southern Ry. 1910. (In Railway & Engng. Rev., v. 50, pp. 33-35, 55-56.)

All of the long, continuous maximum grades have been so reduced that the maximum increase per train load is about 200 tons.

1911—Baltimore & Ohio mountain division improvement. 1911. (In Railway Age Gaz., v. 51, p. 513.)

By reduction of grades, it was made possible to increase the actual tonnage of trains and the distance over which a single engine could haul its full tonnage.

1911—Burch, Edward P.

Electric traction for railway trains, p. 503. 1911. N. Y. McGraw.

Freight haulage by steam locomotives on mountain grades.

Foote, F. S., Jr.

Effect of undulating grades on train velocity. 1911. (In Railway Age Gaz., v. 50, p. 452.)

Theoretical formula.

Morrison, C. J.

Effect of grades on operating costs. 1911. (In Railway Age Gaz., v. 51, p. 111.)

Comparison of cost of freight locomotive repairs and fuel on level and mountainous country for 12 months' period.

Second track construction on the Pennsylvania between Indianapolis and Richmond. 1911. (In Railway Age Gaz., v. 51, p. 133.)

With the completion of the work now under way, the maximum between Richmond and Indianapolis will be reduced to .9 per cent. momentum, and the tonnage rating of 1,350 tons will be materially increased.

1912—Webb, Walter Loring.

Economics of railroad construction, pp. 308-310, 319. Edition 2. 1912. N. Y., Wiley.

Additional cost of operating a given freight tonnage with engines on a heavy ruling grade instead of with engines on lighter grades, etc.

1913—Howard, C. P.

Factors entering into grade reductions. 1913. (In Engng. Record, v. 68, p. 375.)

Analysis of estimated saving in a proposed change from a 0.6 to 0.3 per cent. ruling grade on a typical 130-mile division.

LaBach, Paul M.

Minimum efficient gradient. 1913. (In Railway Age Gaz., v. 55, p. 55.)

The statement is made that the problem is one of virtual grades and speed curves so surrounded by operating conditions that it is unsafe to draw conclusions from similarities based on grade lines alone.

Sakolski, A. M.

American railroad economics, p. 103. 1913. N. Y., Macmillan.

On economy of the reduction of grade, and providing extra tracks, etc.

Webb, Walter Loring.

Economical limits of grade reduction. 1913. (In Railway Age Gaz., v. 54, p. 750.)

Discussion of the factors entering into an analysis of train resistances and their respective importance.

1914—Allowances to short lines of railroads serving industries. 1914. (In Railway Rev., v. 55, p. 602.)

On short haul traffic.

Baxter, W. M.

Operating capacity of single track divisions. 1914. (In Railway Age Gaz., v. 56, p. 869-871.)

Study of the physical limitations in single track operation; advantages of automatic block signals.

Crites, G. S.

Uneconomical track economy. 1914. (In Railway Age Gaz., v. 57, p. 134.)

Tractive force of locomotives in relation to condition of track; illustrated by diagrams.

Heavy improvement work on the Erie; important double tracking, grade revision and realinement between Meadville, Pa., and Corry. 1914. (In Railway Age Gaz., v. 56, p. 125.)

With the building of the second track, the grades and curves have been reduced so as to effect large operating economies.

Howard, C. P.

Grade reduction problems; a study of grades on a 130-mile division. 1914. (In Proc. Amer. Railway Eng. Assoc., v. 15; pt. 2, pp. 3-28.)

Shows saving in operating expenses by reduction of grade.

Abstract. Locating the railroad to handle probable traffic with utmost economy. 1915. (In Engng. Record, v. 71, p. 370.)

Robson, T.

Resistance of locomotives and rolling stock. 1914. (In The Engr., v. 118, p. 18.)

In estimate of power required to haul rolling stock over any section of line considers resistance on straight level track, on curves, due to gravity, due to acceleration.

Shield, A. H.

Economy in locomotive haulage on steep gradients. 1914. (In Engr., v. 118, pp. 383-384.)

Formulas for power required for hauling trains over steep grades.

1915—Calculations showing economy of constructing the Rogers Pass tunnel. 1915. (In Engng. Contracting, v. 44, p. 398.)

Method used is that of comparing cost of fuel on the basis of work done rather than on a train-mile or any other unit.

Comparison of the old and new lines of the Canadian Pacific at Rogers Pass, B. C. 1915. (In Railway Age Gaz., v. 58, p. 194.)

Comparison of comparable factors affecting the cost of operating over Rogers Pass, via present line and via tunnel line, now under construction, average traffic for the years 1912 and 1913.

Kinyon, A. G.

Scientific train loading; tonnage rating. 1915. (In Proc. Traveling Engrs. Assoc., v. 23, pp. 172-213.)

Best method to obtain maximum tonnage haul for the engine over the entire division, taking into consideration the grades at different points in the division.

LaBach, Paul M.

Relation between the number of trains and passing points. 1915. (In Railway Age Gaz., v. 59, p. 197.)

The only general rule that can be formulated is that the slow trains should follow immediately after the fast and be scattered at nearly equal intervals through the day; it is also apparent that increasing the speed will decrease the number of passing points.

LaBach, Paul M.

Superheater locomotives and grade revision. 1915. (In Railway Age Gaz., v. 59, p. 469.)

A comparison of data showing actual saving in cost of operation by reduction of grade and the use of superheater locomotive.

LaBach, Paul M.

Superheater locomotives and grade revision. (Letter.) 1915. (In Railway Age Gaz., v. 59, p. 848.)

Answer to criticism in Railway Age Gaz., v. 59, p. 637.

Superheater locomotives and grade revision. (Letter.) 1915. (In Railway Age Gaz., v. 59, p. 637.)

Criticises the formula given in article by Paul M. LaBach.

1915—Water, F. G., Jr.

Grade reduction on the Kentucky division of the Illinois Central R. R. 1915. (In Railway Rev., v. 57, p. 389.)

As a result of the grade revisions, Mikado engines, which formerly handled trains of only 1,350 tons north bound and 1,450 tons south bound, will now handle 2,250 tons north bound and 3,000 tons south bound.

1916—Howard, C. P.

Rise and fall; fuel and time. 1916. (In Proc. Amer. Railway Engng. Assoc., v. 17, p. 225.)

Power and performance of locomotives in connection with rise and fall of grade.

Operating study of the Rock Island. 1916. (In Railway Age Gaz., v. 60, p. 1065.)

While 53 per cent. of the Rock Island is branch lines, this does not differ greatly from the ratio on other western roads. A considerable portion of branch mileage is in undeveloped country. The 26.4 per cent. of branch line mileage requires 12 per cent. of freight train mileage to handle less than 1 per cent. of total freight business of the division; also has paragraph showing economy of double tracking.

Studies in operation, the Western Maryland. 1916. (In Railway Age Gaz., v. 61, p. 183.)

Revision of line, etc., results in decrease in operating expenses.

1917—Double-track work on a busy section of the Erie Railroad. 1917. In Engng. News, v. 77, p. 224.)

It is of interest to note that the parallel single track lines, for 9 miles, of the Erie Railroad and the Chesapeake & Ohio Railroad, on adjacent right-of-way, are operated by joint agreement as a double-track line. This saves cost of double tracking.

Second track construction on Southern Railway. 1917. (In Railway Age Gaz., v. 63, p. 841.)

The revision of the grade line has enabled the rating for Mikado engines to be increased from 1,400 tons to 2,000 tons.

Second track work on the Union Pacific. 1917. (In Railway Age Gaz., v. 63, p. 329.)

Heavy grade revision was made in connection with the improvement of a dense traffic line in Eastern Utah.

Economic Length, Weight and Speed of Railroad Trains.

Note:—References marked "*" refer to publications that are not in the library and have not been verified.

1883—Laboriette, J. de.

Note sur le wagon dynamometrique du Chemin de Fer du Nord. 1883. (In Rev. Génerale des Chemins de Fer, v. 6, pt. 1, p. 317.)

Contains brief data on the resistance of freight trains; results of tests made in France.

1891—Wellington, Arthur M.

Economic theory of the location of railways, p. 327, 434, 492, 560. 1891. N. Y., Wiley.

Economic effect of the rise and fall of grade; tractive power of the locomotive; train resistance, and train load.

1897—Barbier.

Resistance à la traction des trains de voyageurs à grande vitesse en alignement droit. 1897. (In Rev. Générale des Chemins de Fer, v. 20, pt. 1, p. 272.)

Contains some data on freight train resistance.

1898—Armstrong, Albert H.

Some phases of the rapid transit problem. 1898. (In Trans. Am. Inst. of Elec. Engrs., v. 15, p. 363.)

Problems in electric train acceleration.

Dodd, S. T.

Power consumption in electric railroading. 1898. (In Street Railway Jour., v. 14, p. 545.)

Considers train resistance in four principal divisions: Grade resistance; curve resistance; acceleration resistance; frictional resistance.

1899—McMahon, Peter Valentine.

Electric locomotives in practice, and tractive resistance in tunnels, with notes on electric locomotive design. 1899. (In Jour. Inst. Elec. Engrs., v. 28, p. 508, 609.)

Includes tractive resistance per ton of train and results of performance tests for electric locomotives.

Abstract. 1899. (In Street Railway Jour., v. 15, p. 391.)

Resistance of empty and loaded coal cars. 1899. (In Railroad Gaz., v. 31, p. 262.)

Results of actual tests; half a page.

Resistance of loaded and empty freight cars. 1899. (In Railroad Gaz., v. 31, p. 207.)

Data given by E. H. McHenry; results of actual tests on the Northern Pacific Railway, using a dynamometer; one page.

Speed tests on the Cleveland-Lorain Railway. 1899. (In Street Railway Jour., v. 15, p. 363.)

The line is a high speed electric road, with practically no grades and few curves.

1900—Delano, F. A.

What does it cost to run trains at high speed? 1900. (In Proc. Western Railway Club, v. 12, p. 201-228.)

Considers increased fuel consumption, higher grade of machinery, increased wear and tear, increased risk of accident by breakage of machinery or collisions, delay to traffic on account of keeping the road clear.

1902—Arnold, B. J., and W. B. Potter.

Comparative acceleration tests with steam locomotive and electric motor cars. 1902. (In Trans. Am. Inst. of Elec Engrs., v. 19, p. 833.)

Tests were carried out by W. J. Wilgus, Chief Engr. of the New York Central Railroad.

Arnold, Bion J.

Method of ascertaining by means of a dynamometer car, the power required to operate the trains of the New York Central & Hudson River Railroad between Mott Haven Junction and Grand Central Station and the relative cost of operation by steam and electricity. 1902. (In Trans. Am. Inst. Elec. Engrs., v. 19, p. 865.)

Tests on suburban and through trains, considers speed and weight of train.

Davis, W. J.

Train resistance. 1902. (In Street Railway Jour., v. 19, p. 554.)

Results of tests made for the General Electric Company on a section of the Buffalo & Lockport Railway, on light electric trains.

Mailloux, C. O.

Notes on the plotting of speed-time curves. 1902. (In Trans. Am. Inst. Elec. Engrs., v. 19, p. 901.)

Includes derivation of formulæ, of train acceleration.

1902—Mailloux, C. O.

Plotting speed-time curves. 1902. (In Street Railway Jour., v. 20, p. 51, 121, 199, 231, 254, 275.)

An attempt to facilitate the use of speed-time curves as a method of precision by simplifying their application to practical work.

Results of tests for air resistance on the Berlin-Zossen experimental high speed line. 1902. (In Street Railway Jour., v. 19, p. 726.)

Tests made on electric trains; total motor output required by the 90 to 92 ton cars was from 840 h. p. to 950 h. p. for speeds varying from 90 miles to 106 miles per hour.

1903—Aspinall, John Audley Frederick.

Experiments on the tractive resistance of loaded railway wagons. 1903-04. (In Minutes, Proc. Inst. Civil Engrs., v. 158, p. 369.)

Results of experiments made on the Lancashire and Yorkshire Railway, with 10-ton, 20-ton, and 30-ton cars loaded to their full capacity.

Abstract. Tractive resistance of loaded railway wagons; by J. A. Aspinall. 1905. (In Railroad Gaz., v. 38, p. 15.)

Dennis, A. C.

Virtual grades for freight trains. 1903. (In Trans. Amer. Soc. of Civil Engrs., v. 50, p. 1. Paper 942.)

Contains diagram showing velocity head and train speed; twenty-two pages, including discussion.

Wickhorst, Max H.

Equal tonnage rating, methods of test and calculation. 1903. (In Proc. Western Railway Club, v. 15, p. 317.)

Includes results of tests of freight train resistance; formulas.

Abstract. (In Railroad Gaz., v. 35, p. 234.)

1904—Ashe, Sydney W.

Train testing. 1904. (In Street Railway Jour., v. 23, p. 769.)

Plotting of speed-time curves and also briefly considers distance-time curves.

Davis, W. J., Jr.

Train resistance. 1904. (In Street Railway Jour. v. 24, p. 1000.)

Formula for train resistance at high speeds as applied to the type of cars in common use on electrically operated railroads.

Lyford, O. S., Jr., and W. N. Smith.

Problems of heavy electric traction. 1904. (In Trans. Am. Inst. of Elec. Engrs., v. 23, p. 696, 713.)

Comparative train performances computed with different resistance formulas; and time-speed curves for steam trains from actual practice.

Abstract. 1904. (In Street Railway Jour., v. 24, p. 993.)

1905—Ayer, J. M. and H. S. Knowlton.

Car-test recorder of the Boston Elevated Railway Company. 1905. (In Street Railway Jour., v. 25, p. 68.)

Methods of testing operation of trains, in regard to speed, running time, acceleration, coasting, braking and power consumption

1906—Ashe, Sydney W.

How to analyze train tests. 1906. (In Street Railway Jour., v. 28, p. 1049-1052.)

A study of the results of a train test made by the Brooklyn Rapid Transit Co.; considers distance in miles, maximum speed, speed passing curves, average speed between stations, station stops, initial rate of acceleration.

1906—Electric Railway Test Commission.

Report to the President of the Louisiana Purchase Exposition, p. 463-574. 1906. N. Y., McGraw.

Contains data on train resistance tests of interurban cars.

Wynne, F. E.

Electric railway engineering; general principles relating to the operation of cars or trains. 1906. (In Electric Jour., v. 3, p. 7.)

Tractive effort and power required from standstill to maximum speed; effect of grades and curvature; formulæ.

1907—American Railway Engineering and Maintenance of Way Association.

Train resistance; report of Committee on the Economics of Railway Location. 1907. (In Proc. Am. Ry. Engng. Assoc., v. 8, p. 150.)

Contains results of experiments on resistance in relation to speed of loaded and empty freight cars.

Carus-Wilson, Charles Ashley.

Predetermination of train resistance. 1907-08. (In Minutes, Proc. Inst. Civil Engrs., v. 171, p. 227.)

Includes results of tests made on the resistance of freight trains.

Muhlfeld, J. E.,

Tonnage rating. 1907. (In Amer. Engr. & Railroad Jour., v. 81, p. 185.)

Formula for maximum available hauling capacity of locomotive; and discussion of combination of speed and load that may give the best results; one page.

Stillwell, Lewis B., and H. St. C. Putnam.

On the substitution of the electric motor for the steam locomotive. 1907. (In Trans. Am. Inst. Elec. Engrs., v. 26, pt. 1, p. 72.)

Data showing average train-miles, car-miles, ton-miles, weight and speed of trains in passenger and car service in the United States.

Poland, W. B.

Comparative cost of fast and slow freight service. 1908. (In Proc. Amer. Railway Engng. & Maintenance of Way Assoc., v. 9, p. 795.)

Four pages, including diagram.

1908—Raymond, William G.

Elements of railroad engineering, p. 133, 158. 1908. N. Y. Wiley.

Treats of variation of tractive effort with speed; resistance to motion at constant velocity; train acceleration; grade resistance, etc.

1909—Ayres, M. V.

Car weights as affecting operating cost. 1909. (In Elec. Railway Jour., v. 34, p. 744.)

An attempt to show the manner in which the following costs vary with the weight of cars: Cost of power; Cost of car repairs; Cost of track repairs; fixed charges of power plant; and fixed charges of distribution system.

Beahan, Willard.

Field practice of railway location, p. 151. 1909. N. Y., Engineering News Publishing Co.

Considers train resistance, velocity resistance, length of train, etc.

1909—Bissell, C. S.

Maximum weights of slow freight trains. 1909. (In Trans. Amer. Soc. Civil Engrs., v. 64, p. 303, Paper 1111.)

Determination of the car factor in train resistance.

Abstract. 1909. (In Railway Gaz. (Lond.), v. 10, p. 609.)

Mailloux, C. O.

Industrial definition and measurement of train-acceleration. 1909. (In Elec. Ry. Jour., v. 23, p. 277.)

Abstract of paper read before the International Electrical Congress at Marseilles. Gives diagram of distance speed and acceleration functions.

Performance of electrical equipment on the Liverpool & Southport railway. 1909. (In Elec. Ry. Jour., v. 33, p. 946.)

Particulars of acceleration, train resistance, with diagrams for speed time curves and tractive effort.

1910—Bissell, Clinton S.

Traction of freight trains at different speeds. 1910. (In Trans. Amer. Soc. Civil Engrs., v. 66, p. 58, Paper 1132.)

An attempt to determine what a given tractive power can accomplish in overcoming a number of resistances, the principal of which is grade.

Cars, schedules, power consumption, running tests and signals in London subways. 1910. (In Elec. Ry. Jour., v. 36, p. 212.)

Considers also weight and length of train.

Dennis, A. C.

Basis of variation for operating costs applicable to the design of railway location. 1910. (In Proc. Amer. Ry. Engng. & Maintenance of Way Assoc., v. 11, pt. 1, p. 685.)

States that the tests of freight train resistance given cover speeds of 7 to 35 miles an hour.

Isaacs, John D., and E. E. Adams.

Economic and efficient speed of freight trains. 1910. (In Proc. Amer. Ry. Engng. & Maintenance of Way Assoc., v. 11, pt. 2, p. 1328.)

Nine pages, including diagrams.

Abstract. Engng. Record, v. 60, p. 657-658.)

Isaacs, John D., and E. E. Adams.

Effect of physical characteristics of a railway upon the operation of trains. 1910. (In Proc. Amer. Ry. Engng. & Maintenance of Way Assoc., v. 11, pt. 2, p. 1311.)

Randolph, Beverly S.

Locomotive performance on grades of various lengths. 1910. (In Trans. Amer. Soc. Civil Engrs., v. 70, p. 321.)

A careful study of train resistance due to grades and alignment, distributing this resistance so as to secure a minimum cost of operation with the means available for construction.

Schmidt, Edward C.

Freight train resistance. 1910. (In Jour. Amer. Soc. Mech. Engrs., v. 32, p. 679, 1295.)

Gives results of experiments and includes discussion.

Schmidt, Edw. C.

Freight train resistance, its relation to average car weight. 1910. (In Bull. No. 43, Univ. of Illinois Engng. Experiment Station.)

A figure showing relation between speed and resistance, follows the table of results for each test.

Schmidt, Edw. C.

Freight train resistance, its relation to average car weight.

1910. (In Proc. Amer. Ry. Master Mechanics' Assoc., v. 43, p. 264-306.)

Tests to determine the resistance of freight trains under the usual conditions of operation, and at different speeds.

Van Zandt, J. G.

Tonnage rating for fast freight trains. 1910. (In Railway Age Gaz., v. 48, p. 1547-1550, 1788-1794.)

Method for adjusting tonnage and speed ratings of freight trains, with examples and the computations and data on which it is based.

1911—Burch, Edw. P.

Electric traction for railway trains, p. 401. 1911. N. Y., McGraw.

Considers power required for electric trains, including weight of the cars hauled; speed of the train; available traction coefficient; character of the tractive effort; tractive resistance or effort per ton, for gravity, friction and acceleration.

Foote, F. S., Jr.

Effect of undulating grades on train velocity. 1911. (In Railway Age Gaz., v. 50, p. 452.)

One and a half pages.

Murray, William S.

Electrification analyzed, and its practical application to trunk line roads, inclusive of freight and passenger operation. 1911. (In Trans. Am. Inst. Elec. Engrs., v. 30, pt. 2, p. 1394-1404.)

Study of the capacity of engines required and coal consumed in such services, over the 61.5 miles of route between New Haven and Woodlawn; also results of a series of tests on the requirement of a freight engine on a trunk from a steam locomotive point of view.

Some studies in railway operating ratios. 1911. (In Railway & Engng. Rev., v. 51, p. 107, 129, 151, 171, 193, 215, 249, 285, 307, 327, 349, 369, 433, 455, 669, 870.)

Considers expense of locomotive repairs compared with revenue loads carried, cost of fuel and train service. Includes tractive power of locomotives, capacity of freight cars and tons carried per train-mile.

Speed and acceleration problem. 1911. (In Amer. Engr. & Railroad Jour., v. 85, p. 421-424.)

Method of determining speed and time with any assumed train, for any particular section of an existing or proposed road.

Wickhorst, M. H.

Tonnage rating of locomotives on the Burlington. 1911. (In Bull. 138, Amer. Ry. Engng. Assoc.)

For practical use, the rates decided upon are made out on tonnage rating sheets for each division.

Abstract. Ry. Age Gaz., v. 51, p. 592-597.)

Freight train tests on an electric interurban railway. 1912. (In Trans. Amer. Inst. Elec. Engrs., v. 31, pt. 1, p. 1001.)

Treats of train friction, grade resistance, power consumption, acceleration.

Droege, John A.

Freight terminals and trains, p. 139, 152, 168. 1912. N. Y., McGraw.

Treats of loading cars; formulæ for train resistance; and results of tests on the Baltimore & Ohio S. W. R. R., on the relative economy of running slow-freight trains, with engines loaded to maximum capacity, compared with fast-freight trains of less than maximum capacity of engines.

1912—Webb, Walter Loring.

Economics of railroad construction, p. 186-232. Ed. 2. 1912. N. Y., Wiley.

On train resistance, tonnage rating, momentum grade, etc.

1913—American Railway Engineering Association.

Economics of railway location. 1913.

Analysis of maintenance of way and structure accounts.

American Railway Engineering Association.

Ratio of locomotive equivalent, ton mileage to total. 1913. (In Proc. Amer. Ry. Engng. Assoc., v. 14, p. 597-598.)

Table given to show approximate amount of damage done by the locomotive for each class of traffic.

Begien, R. N.

Dynamometer tests, Baltimore & Ohio Railroad, application to tonnage rating. 1913. (In Proc. Am. Ry. Engng. Assoc., v. 14, p. 599-651.)

Tests to determine a standard by which train performance may be measured.

Abstracts. Engng. News, v. 69, p. 727-729; Engng. Record, v. 67, p. 315-16, 349-351; Ry. Rev., v. 53, p. 322-324; Ry. Age Gaz., v. 54, p. 642.

Del Mar, W. A., and D. C. Woodbury.

Approximate predetermination of train energy. 1913. (In Elec. Ry. Jour., v. 42, p. 1055.)

One and three-quarters pages.

de Muralt, C. L.

Principles of electric railroading. 1913. (In Ry. Age Gaz., v. 54, p. 808-09, 1031-1032.)

Considers train resistance, formulas developed for calculating the amount of the forces of inertia, gravity and friction.

Houston, Harold A.

Comparison of freight train and canal boat resistance. 1913. (In Railway Age Gaz., v. 55, 958.)

Contains diagram of relation between tractive effort and speed for freight trains and canal barges.

Houston, H. A.

Locomotive tractive effort. 1913. (In Railway Age Gaz., v. 55, p. 455.)

The development of a formula which includes allowances for the limits to the physical strength of the fireman.

Hutchinson, Cary T.

Predetermination of train energy. (Letter) 1913. (In Elec. Ry. Jour., v. 42, p. 1295-1296.)

Discusses formulas for train resistance.

Predetermination of energy to propel cars or trains. (Editorial) 1913. (In Elec. Ry. Jour., v. 42, p. 1166.)

Review of a number of formulas for this purpose.

Roberts, Clarence and Russell M. Smith.

Practical locomotive operation, p. 13, 17. 1913. Phila. Lippincott.

Tractive effort and horse power formulæ for locomotives and formulas for train resistance with passenger and freight cars, with diagrams.

Sakolski, A. M.

American railroad economics, p. 127, 158. 1913. N. Y., Macmillan.

On speed, efficiency, hauling capacity, etc., of rolling stock, general remarks.

Sheafe, J. S.

Overloading freight locomotives not economical. 1913. (In Railway Age Gaz., v. 55, p. 915.)

Figures are presented for consideration in order to reduce the whole question to a percentage basis.

Studies in operation—the Chesapeake & Ohio. 1913. (In Ry. Age Gaz., v. 55, p. 1061.)

An increase of 187 tons in train load in two years, and what is being done to reap the profit of this gain in efficiency.

Tonnage rating economics. (Editorial) 1913. (In Railway & Engng. Rev., v. 53, p. 328-329.)

Review of paper read before the Amer. Ry. Engng. Assoc. by R. N. Begien.

Train resistance tests, Southern Pacific Ry. 1913. (In Engng. News, v. 69, p. 410-411.)

A description of a series of careful observations made with regular freight trains, in 1883.)

1914—American Railway Master Mechanics Association.

Report of Committee on Train Resistance and Tonnage Rating. 1914. (In Proc. Am. Ry. Master Mechanics Assoc., v. 47, pt. 1, p. 284-323.)

Considers track conditions, operating conditions, weight of cars, etc.

Dunn, Harold H.

Tractive resistance of a 28-ton electric car. 1914. (In Univ. of Illinois, Engng. Experiment Station, Bull. No. 74.)

Tests on interurban electric car running on straight, level track, in still air at uniform speed, to determine the resistance offered and to ascertain the relation existing between that resistance and the speed of the car.

Ewing, D. D.

Resistance to car motion. (Letter) 1914. (In Elec. Ry. Jour., v. 44, p. 304-305.)

Discussion of tests made at the Univ. of Illinois.

Freight car maintenance record, 1902-1912-1913. 1914. (In Railway Rev., v. 54, p. 32.)

Statistics for a number of railroads.

Houston, H. A.

Analysis of steam train resistance. 1914. (In Railway Age Gaz., v. 56, p. 741.)

Study of a number of tests to determine the average value of the various items concerned.

Kerby, Frederick.

Advantages derived from the use of speed recorders, and the influence of same on operating expenses. (1914. (In Proc. Traveling Engrs. Assoc., v. 22, p. 371-385.)

It is claimed that by maintaining as uniform a speed as possible over an entire division of road, it is much easier on track, machinery and cars and reduces expenses of maintenance.

Mailloux, C. O.

Notes on train resistance formulas. (Letter) 1914. (In Elec. Railway Jour., v. 44, p. 78-79.)

Discusses new empirical formula derived from the tests made by the experiment station of the University of Illinois.

1914—Mott, Albert G.

Economical train loading for a given territory. 1914. (In Ry. Age Gaz., v. 56, p. 1579.)

Relation of cost, train load and speed, results of experiments.

Mounce, R. S.

Simplifying the tonnage rating problem. 1914. (In Railway Age Gaz., v. 56, p. 425.)

Details of a method which has been in constant use for four years on an important trunk line.

Robson, T.

Resistance of locomotives and rolling stock. 1914 (In Engineer, v. 118, p. 18.)

A formula for estimating power required for hauling rolling stock over any section of line; one and a quarter pages.

1915—Barnum, E. S.

Road trials to determine tonnage rating. 1915. (In Railway Age Gaz., v. 59, p. 1095.)

Data for determination of scientific train loading; result of tests.

Beyer, O. S., Jr.

Scientific train loading, tonnage rating. 1915. (In Railway Age Gaz., v. 59, p. 507.)

Includes a table of value of internal resistance in pounds per ton gross weight of freight cars of various weights at different speeds.

Same. Ry. Age Gaz. (Mech. ed.), v. 39, p. 502; Ry. Rev., v. 57, p. 594.

Beyer, O. S., Jr.

Scientific train loading; tonnage rating. 1915. (In Railway Rev., v. 57, p. 594.)

Treats of drawbar pull of locomotive; train resistance; determination of train weights; car factor method of tonnage adjustment; adjustments for weather and other conditions; and determination of maximum adjusted tonnage rating.

Cost of train limit legislation. 1915. (In Railway Age Gaz., v. 58, p. 979.)

A detailed estimate showing that proposed Illinois law limiting the number of cars hauled in one train to 50 would render valueless investments made by the Chicago, Milwaukee & St. Paul Ry. Co. in Illinois and would involve an increase in freight train miles of 20.08 per cent.

Dodgson, F. L.

Location of passing sidings on single track. 1915. (In Railway Age Gaz., v. 59, p. 1197.)

Considers how to place the sidings so that the maximum capacity of the railroad will be obtained.

Dow, Marcus A.

Safety and short trains. 1915. (In Railway Age. Gaz., v. 58, p. 1006-08.)

On the bill to limit the length of trains to a maximum of 50 cars per train.

Early tonnage studies. 1915. (In Railway Age Gaz., v. 59, 972.)

Historical review, showing limitations of eighty years ago.

Eddy, C. L.

Rolling resistance of cars over switches and frogs. 1915. (In Proc. Amer. Ry. Engng. Assoc., v. 16, pt. 2, p. 279-297.)

Tests made in freight yard of Lake Shore & Michigan Southern Ry. Co., Collinwood, Ohio; results were analyzed for effect of variations in the initial velocity upon total resistance; no definite conclusions because of limited range of velocities.

Abstracts. Ry. Age. Gaz., v. 58, p. 796; Engng. News, v. 73, p. 899; Sci. Am. Suppl., v. 80, p. 111.

Goodwin, George S.

Value of a locomotive in terms of earning capacity. 1915. (In Ry. Age Gaz., v. 58, p. 305.)

Earning capacity analyzed.

Green, F. W.

Cost of stopping and starting trains. 1915. (In Proc. Amer. Ry. Engng. Assoc., v. 16, pt. 2, p. 271-278.)

On developing formula for approximate cost; review of papers on this subject.

Abstracts. (In Railway Rev., v. 56, p. 655.)

Limiting the length of trains. (Editorial) 1915. (In Ry. Age Gaz., v. 58, p. 392.)

States that the two strongest arguments against train limit legislation are that it will increase both railway expenses and railway accidents.

Locomotive maintenance. 1915. (In Ry. Age Gaz., v. 59, p. 452.)

Diagram showing that the roads that have increased the capacity of their freight locomotives have been able to increase the ton-miles per locomotive-mile.

Pomeroy, L. B.

Diagram for determining percentage of maximum tractive effort. 1915. (In Ry. Age Gaz., Mech. Ed., v. 89, p. 453-454.)

Method of determining by means of combination curves tractive effort available with various speeds.

Potter, M. W.

Limiting length of trains by law. 1915. (In Ry. Age Gaz., v. 58, p. 268.)

Argument against limiting the length of trains.

Price, Alfred.

Some maxima and minima in train operation. 1915. (In Ry. Age Gaz., v. 58, p. 401.)

Considers speed and weight of trains and car loading in relation to cost of operation.

Same. (In Ry. Rev., v. 56, p. 286-289.)

Tests (1912-1913) on the resistance of passenger locomotives and cars on the Russian railway system. 1915. (In Jour. Amer. Soc. Mech. Engrs., v. 36, p. 0144-0147.)

Gives formulas derived by the author from actual tests.

Wentworth, Charles C.

Hump-yard calculations. 1915. (In Engng. News, v. 74, p. 750.)

A formula expressing the motion of cars when drifting either on a level or on up- or down-grades.

1916—American Railway Master Mechanics' Association.

Report of Committee on Train Resistance and Tonnage Rating. 1916. (In Proc. Am. Ry. Master Mech. Assoc., v. 49, p. 416-445.)

Data determined by tests conducted on the Pennsylvania Railroad, with higher capacity cars than those reported by committee, previously.

Barnum, E. S.

Measuring locomotive performance. 1916. (In Railway Age Gaz., v. 60, p. 240.)

On method of making ton mileage report.

1916—Boutell, Hugh G.

Interesting facts concerning grade resistance and car friction. 1916. (In Ry. Mech. Engr., v. 90, p. 345-346.)

Results of tests are given.

Cause of shock in long freight trains. 1916. (In Ry. Mech. Engr., v. 90, p. 21-22.)

States the best results in railroad train service were obtained when the resistance of the ends of the cars exceeded the carrying capacity of the cars.

Ewing, D. D.

Initial resistance to car motion. 1916. (In Elec. Ry. Jour., v. 48, p. 974.)

Some measurements of the forces necessary to start different types of cars.

Long freight trains and railway accidents. 1916. (In Ry. Age Gaz., v. 60, p. 1033.)

A study of the relation between train length and accidents to trains and casualties to persons.

McKenzie, Edward F.

Train handling on heavy grades. 1916. (In Ry. Age Gaz., v. 61, p. 510.)

Shows methods used on the Pennsylvania Railroad.

Wood, A. J.

Kiesel train resistance formulas. 1916. (In Ry. Mech. Engr., v. 90, p. 627-627.)

Kiesel method for determining tractive effort of a locomotive.

Wood, Arthur Julius.

Principles of locomotive operation and train control, p. 13, 33, 45. 1915. N. Y., McGraw.

Tractive effort, forces which move a locomotive; acceleration of trains; train resistance, including speed, grade, acceleration, curve flange and other resistances.

Beyer, O. S., Jr.

Application of simple principles. 1917. (In Ry. Age Gaz., v. 63, p. 64.)

On adjusting train weights.

Burke, J. A.

Slack action in long passenger trains, its relation to triple valves of different types and consequent results in the handling of trains. 1917. (In Railway Rev., v. 60, p. 629, 653.)

Considers the passenger car brake in its relation to length and weight of train.

1917—Burke, M. E.

Tonnage bureau. 1917. (In Ry. Age Gaz., v. 63, p. 63.)

On method of dealing with the problem of tonnage rating on railroads.

Foley, T. J.

Effect of speed restrictions on the movement of trains. 1917. (In Railway Rev., v. 61, p. 630.)

Statistics to show the importance of limiting the speed of trains and the additional tons of freight that could be carried in a year with same equipment and expenditure.

Moore, Lewis E.

Distribution of loading on trains. (Letter) 1917. (In Railway Age Gaz., v. 62, p. 300.)

Discusses the question as to why a train pulls harder with the empties in front and the loads in the rear.

Operating conditions affecting tonnage. 1917. (In Ry. Age Gaz., v. 62, p. 848-850.)

Discussion of the fundamental principles governing train loading; measures to secure maximum performance.

Schmidt, Edw. C., and Harold H. Dunn.

Passenger train resistance. 1917. (In Proc. Amer. Ry. Engng. Assoc., v. 18, pt. 1, p. 689-700.)

Results of tests made at the Engineering Experiment Station, Univ. of Illinois.)

Schmidt, E. C., and H. H. Dunn.

Resistance of passenger train equipment. 1917. (In Bull. No. 194, Am. Ry. Engng. Assoc.)

Results of a study made with a dynamometer car, of modern cars operating under actual service conditions.

Abstracts. 1917. (In Ry. Age Gaz., v. 62, p. 407; Ry. Rev., v. 60, p. 296; Ry. Mech. Engr., v. 91, p. 247.)

Sullivan, J. G.

Truck resistance on curves. (Letter) 1917. (In Ry. Age Gaz., v. 62, p. 731.)

Criticizes Lewis E. Moore theory as to why a train would pull harder around a curve with the loaded cars behind the empties.

Wilson, W.

Some practical illustrations. 1917. (In Ry. Age Gaz., v. 63, p. 347.)

On train loading; engine efficiency, and train miles.

Economic Length of Train Divisions; Short Haul Traffic; and Terminal Railroads.

1891—Wellington, Arthur M.

Economic theory of the location of railways, p. 732-736. N. Y., Wiley.

On the economy of short haul traffic.

1908—Raymond, William G.

Elements of railroad engineering, p. 213, 229, 235. 1908. N. Y., Wiley.

Effect on operating expenses of change in number of trains, tonnage remaining constant; cost per train mile of operating distance only; problems in saving due to a reduction of distance, etc.

1912—Droege, John A.

Freight terminals and trains, p. 20. 1912. N. Y., McGraw.

Contains very brief reference to length of divisions on railroads.

1913—Prall, W. M.

Terminal service. 1913. (In Railway & Engng. Rev., v. 53, p. 574.)

On movement of cars, etc.

Sakolski, A. M.

American railroad economics, p. 146. 1913. N. Y., Macmillan.

Treats of average length of haul, etc.; general remarks.

1914—Comparative study in operation—Virginian and C. C. & O. 1914. (In Railway Age Gaz., v. 56, p. 935.)

Contains data on operating divisions.

Coss, J. L.

Local freight train service. 1914. (In Railway Age Gaz., v. 56, p. 1517.)

Makes statement that a local train should not be made a tonnage train; the maximum tonnage should be handled by all engines whenever possible, but the local service cannot be performed to the best advantage if the engine is burdened to the full rating.

1914—Detroit terminal railroad. 1914. (In Railway Age Gaz., v. 56, p. 1522.)

Terminal line serving industrial plants around the city of Detroit.

Farmer, R. R.

Handling of local or way-freight trains. 1914. (In Railway Age Gaz., v. 57, p. 1117.)

Kimball, Geo. H.

Unification of the freight terminals of a large city. 1914. (In Proc. Amer. Railway Engng. Assoc., v. 15, p. 29-46.)

Special problems of the city of Buffalo.

Mott, Albert G.

Economical train loading for a given territory. 1914. (In Railway Age Gaz., v. 56, p. 1579.)

Empirical method for determining train loading, tested on Coast Line Division of Southern Pacific.

Studies of operation—the Pittsburgh & Lake Erie. 1914. In Railway Age Gaz., v. 56, p. 307.)

Contains data on length of haul, operating ratio, density of traffic.

1915—Garner, F. H.

Local freight train. 1915. (In Railway Age Gaz., v. 59, p. 394.)

On short haul traffic.

1916—Wood, P. O.

Assignment of power from standpoint of efficient service and economy in fuel maintenance. 1916. (In Proc. Traveling Engrs. Assoc., v. 24, p. 272-309.)

On the economy of running engines through more than one division.

Wymond, Mark.

Railroad valuation and rates, p. 91, 272. 1916. Chic., Wymond & Clark.

Contains data on the effect of distance, curvature and grades on operating expenses; also gives Illinois mileage distance scale, showing that rate per ton increases with distance but not nearly so fast.

Glass, J. J.

Use of tonnage diagrams. 1917. (In Railway Age Gaz., v. 63, p. 66.)

States that divisions on some railroads are too long.

1917—Green, F. W.

Economical tonnage rating for way freight trains. 1917. (In Railway Age Gaz., v. 63, p. 384-385.)

States that as a general rule, it is better economy to shorten local districts than to reduce tonnage ratings.

Transportation expenses on the Katy; analysis made of the reasons for the comparatively small trainload and suggestions for obtaining better results. 1917. (In Railway Age Gaz., v. 62, p. 401.)

Data on freight train performance, length of haul, etc.

Wilson, W.

Some practical illustrations. 1917. (In Railway Age Gaz., v. 63, p. 347.)

On train loading at division yards.

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Am. Ry. Master Mechanics' Assoc., 1910-16;
Roadmasters & M. & W. Assoc., 1908-13.

Economic Standards of Maintenance of Way.

1891—Wellington, Arthur M.

Economic theory of the location of railways, p. 118, 762. Edition 5. N. Y., 1891. Wiley.

Contains data on economics of maintenance of way standards.

1906—Smith, F. A.

Maintenance of way standards on American railways and rules and instructions governing roadway departments. 1906. N. Y., Myron C. Clark.

Compilation of codes and standards governing trackmen of American roads from the Atlantic to the Pacific.

1911—Efficiency methods in the maintenance-of-way department of the Erie Railroad. 1911. (In Engng. Record, v. 64, p. 485.)

System providing close supervision, conduct of work by schedule and standardization of detail operations.

1912—Beyer, O. S.

Standard practice cards on the Erie. 1912. (In Railway Age Gaz., v. 52, p. 1108.)

Approved methods for performing different maintenance of way operations.

Lindsay, C. E.

Efficiency in track maintenance. 1912. (In Railway Age Gaz., v. 52, p. 1112-1114.)

The elements of cost in maintenance work; and graphical method of showing costs.

Some roadbed and track standards of the B., R. & P. Ry. 1912. (In Railway & Engng. Rev., v. 52, p. 758-761.)

Information of some of the standard plans, designs and methods, pertaining to the maintenance of way department, Buffalo, Rochester & Pittsburgh Ry.

1913—American Railway Engineering Association.

Analysis of maintenance of way and structure accounts. 1913. (In Proc. Amer. Railway Engng. & Maintenance of Way Assoc., v. 14, p. 580-596.)

Report of Committee; considers main tracks and side tracks.

Lewis, E. R.

Cost and how to count it. 1913. (In Railway Age Gaz., v. 54, p. 1082.)

Percentages of labor expended on maintenance units in terms of one mile of main track.

1915—Powers, J. W.

Economy in track work and its relation to rolling stock. 1915. (In Railway Age Gaz., v. 58, p. 479.)

On the necessity of raising the standard of track maintenance, commensurate with the demands made upon them with the increase in train load.

1916—American Railway Engineering Association.

Report of Committee on Economics of Track Labor. 1916. (In Proc. Amer. Railway Engng. Assoc., v. 17, p. 370.)

A chart outlining a suggested method of analyzing the results of track sections; enabling a relationship to be established between units of labor performed and physical characteristics.

Cost of spur tracks. 1916. (In Coal Age, v. 9, p. 999.)

Recent costs for various lengths of track, according to Massachusetts practice.

Cram, R. C.

Units for comparing costs for track upkeep. (Letter) 1916. (In Electric Railway Jour., v. 48, p. 363.)

A criticism of an editorial on this subject.

Grills, A.

Equating track values. 1916. (In Railway Age Gaz., v. 61, p. 515.)

A study to determine how the proper standard of maintenance may best be obtained.

Mitchell, L. A.

Unit for comparing track upkeep costs. (Letter) 1916. (In Electric Railway Jour., v. 48, p. 403.)

A criticism of an editorial on this subject.

Stimson, Earl.

System for standardizing maintenance of way work. 1916. (In Proc. Amer. Railway Engng. Assoc., v. 17, p. 247-263.)

Describes methods of the Baltimore & Ohio Railroad.

Units for comparing track upkeep costs. (Editorial) 1916. In Electric Railway Jour., v. 48, p. 301.)

Track maintenance cost may be grouped roughly into three classes, legal or community requirements; destructive forces of nature and of vehicular traffic; and destructive forces which originate in the conduct of transportation.

Units of Operating Expenses for Railroads.

Note:—Entries marked "+" refer to publications that are not in the Library and have not been examined.

1891—Wellington, Arthur M.

Economic theory of the location of railways, p. 106, 560. Edition 5. N. Y., 1891. Wiley.

The general nature of the causes which modify operating expenses and especially the effect thereon of differences of alignment.

1907—Stillwell, Lewis B., and H. St. C. Putnam.

On the substitution of the electric motor for the steam locomotive. 1907. (In Trans. Am. Inst. of Elec. Engrs., v. 26, pt. 1, p. 49.)

Gives table of expense for maintenance of way and structures; maintenance of equipment; conducting transportation; and general expenses; in this way showing classification of accounts.

1908—Raymond, William G.

Elements of railroad engineering, p. 208. 1908. N. Y., Wiley.

Gives classification of operating expenses.

1910—Cunningham, W. M.

Economics of railroad maintenance of way. 1910. (Jour. of Accountancy, March.) +

Gives an outline of railway maintenance, with tables showing relative cost, explaining the policy of better roads.

Interstate Commerce Commission's own investigation of the costs of railway operation. 1910. (In Railway Age Gaz., v. 49, p. 1108.)

Ratio of operating costs on several railroads.

1911—Morrison, C. J.

Maintenance of equipment costs. 1911. (In Railway Age Gaz., v. 50, p. 1303-1308.)

Illustrated with diagrams.

Some studies in railway operating ratios. 1911. (In Railway & Engng. Rev., v. 51, p. 107, 129, 151, 171, 193, 215, 249, 285, 307, 327, 349, 369, 433, 455, 669, 870.)

Includes analysis of relation of maintenance accounts to expense of conducting transportation.

Wood, B. F.

Electrical operation of the West Jersey & Seashore Railroad. 1911. (In Trans. Am. Inst. Elec. Engr., v. 30, pt. 2, p. 1382.)

Cost of operation, showing main subdivisions.

1912—Cleveland, Frederick A., and F. W. Powell.

Railroad finance, p. 195-212. 1912. N. Y., Appleton.

On classification of operating accounts, freight and passenger statistics, etc.

Passage, C. D.

Cost accounting in the engineering department. 1912. (In Railway Age Gaz., v. 53, p. 578-581.)

Complete and convenient system developed on the Northern Pacific for construction and maintenance work.

Ripley, William Z.

Railroads, rates and regulations, p. 49-70. 1912. N. Y., Longmans.

Contains data on the relative importance of the principal items under railroad expenditures.

Strombeck, J. F.

Freight classification, a study of underlying principles, p. 11-13, 124-125. 1912. N. Y., Houghton.

Contains analysis of railroad expenditures.

Webb, Walter Loring.

Economics of railroad construction, p. 89. Edition 2. 1912. N. Y., Wiley.

Classification of operating expenses, unit costs and analysis of cost.

1913—Beyer, O. S., Jr.

Factors in the selection of locomotives in relation to the economics of railway operation. 1913. (In Jour. Amer. Soc. Mech. Engrs., v. 35, p. 19.)

Relation of operating expenses to the selection of motive power.

Division of operating expenses. 1913. (In Railway & Engng. Rev., v. 53, p. 345.)

Shows unit costs of operation.

Eaton, J. Shirley.

Handbook of railroad expenses. 1913. N. Y., McGraw.

An attempt to set out in analytical exhibits the complex process of railroad operation accounting; the statistical tables in their order and relation giving the whole philosophy of operation accounts.

Heckman, A. V.

Forms for locomotive operation and cost. 1913. (In Railway Age Gaz., Mech. Edition, v. 87, p. 124.)

Comprehensive office records to show the value of a locomotive from the standpoint of service or efficiency.

Locomotive maintenance costs, records of 1902, 1912 and 1913 compared. 1914. (In Railway Rev., v. 54, p. 371.)

Gives average tractive power in tons and average number of tons revenue freight per train load on thirty-three representative railroad systems.

Railroad cost and efficiency. 1913. (In Railway Age Gaz., v. 55, p. 58.)

On ratio of costs between passenger and freight service.

Sakolski, A. M.

American railroad economics, p. 195. 1913. N. Y., Macmillan.

On principles of units of operating expenses.

1914—Bowser, J. T.

Comparison of maintenance of way costs on a mileage basis. 1914. (In Railway Age Gaz., v. 57, p. 337.)

Brief general statement.

Division of freight and passenger expenses. 1914. (In Railway Age Gaz., v. 57, p. 153.)

New and old formulas contrasted and the newest formula applied to the 1914 classification of expenses.

Increase in maintenance of way expenses on the P. R. R. 1914. (In Railway Rev., v. 54, p. 573.)

Shows units of maintenance expense.

Maintenance of equipment expense, Pennsylvania R. R. 1914. (In Railway Rev., v. 54, p. 570.)

An analysis of the various causes leading to the increased cost of maintenance is given.

One road's answers to the Commission's questions 42 to 45; the Pittsburgh & Lake Erie describes economies resulting from large capacity cars and heavy locomotives, 1914. (In Railway Age Gaz., v. 56, p. 1073.)

Contains table demonstrating locomotive's part in reducing cost of train operation. Table based on cost of 1,000,000 "loaded ton miles."

Text of Commission's accounting order in re separation of operating expenses. 1914. (In Railway Age Gaz., v. 57, p. 206.)

On the proposal that the railroads should report separately the greater portion of their freight and passenger expenses, certain common expenses being left unapportioned.

Hooper, William E.

Railroad accounting, p. 147-206. 1915. N. Y., Appleton.

On traffic and transportation expenses, classification of accounts.

1915—Railroad's maintenance expenses allocated between freight and passenger service. 1915. (In Engng. Rec., v. 72, p. 226-229.)

Percentages used, and reasons therefore in rate case studies made by William J. Wilgus for the Ulster & Delaware Railroad.

Hutchins, F. Lincoln.

Efficient railroad records. 1916. (In Railway Rev., v. 58, p. 409.)

On line-of-road units.

1916—LaBach, Paul M.

Is the ton-mile the proper basis for allocating railroad operating costs? 1916. (In Engng. Record, v. 73, p. 639.)

Questions whether maximum loads are not more pertinent than total tonnages, and should not more weight be given to deterioration independent of traffic.

Record of ten years: Tractive power; train loads; car capacity; carloads and ton-mile cost of locomotive maintenance; freight car maintenance; and fuel. 1916. (In Railway Rev., v. 58, p. 326-327.)

Figures taken from records of railways filed with the Interstate Commerce Commission.

1916—Rockwood, John A.
Proper basis for allocation of maintenance expenses. 1916. (In Engng. Record, v. 74, p. 55.)
Discussion of Paul M. La Bach's article on analysis of railroad operating expenses.
Sakolski, A. M.
Railroad operating expenses and property values. 1916. (In Jour. of Accountancy, v. 22, p. 101.) +
Wymond, Mark.
Railroad valuation and rates, p. 217, 218. 1916. Chic., Wymond & Clark.
Contains summary, showing classification of operating expenses and also discusses apportionment of expense between various classes of traffic.
1917—Comparisons of monthly operating expenses. (Letter) 1917. (In Railway Age Gaz., v. 62, p. 215.)
On the monthly analysis of transportation expenses by divisions.
Hopkins, J. H.
Monthly analysis of operating expenses. 1917. (In Railway Age Gaz., v. 62, p. 21.)
A plan formulated for measuring division expenses on the unit cost basis.
1917—Locomotive and freight car capacities and loads. 1917. (In Railway Rev., v. 60, p. 869.)
Maintenance costs of freight cars and freight locomotives per ton-mile; cost of fuel for freight locomotives per ton-mile, for fiscal year 1916.
System of auditing on the Boston & Maine. 1917. (In Railway Age Gaz., v. 63, p. 502.)
Waybills or copies of waybills are forwarded daily by the station freight agents to the office of auditor freight receipts; the data on waybills is perforated on cards by punching machine, the cards form basis of subsequent operations performed automatically on sorting machines and tabulator printers.

Economics of Locomotive Firing.

1904—Fuel tests on the Furness Railroad, England. 1904. (In Railroad Gaz., v. 36, p. 156.)
Determination of fuel value for locomotives, of several grades of coal.
1909—Wright, S. D.
Fuel economy. 1909. (In Proc. Traveling Engrs. Assoc., v. 17, p. 41-107.)
Design of locomotives, etc., in relation to fuel economy.
1910—Benjamin, C. H., and Louis E. Endsley.
Locomotive performance under different degrees of superheated steam. 1910. (In Proc. Amer. Railway Master Mechanics' Assoc., v. 43, p. 208.)
Gives coal consumption under different pressures and with superheaters.
Fuel economy on testing plants and railways. 1910. (In Ry. & Eng. Rev., v. 50, p. 171.)
Abstract of paper read before the Western Railway Club.
Hayes, W. C.
Education as an essential of fuel economy. 1910. (In Proc. Amer. Ry. Master Mech. Assoc., v. 43, p. 93-111.)
On selection of candidates and educational plan, before and after employment of firemen.

1910—Traveling Engineers' Association.

Fuel economy. 1910. (In Proc. Traveling Engrs. Assoc., v. 18, p. 211-295.)

Report of a committee; discusses the design of the locomotive; firing practice, and quality of coal used.

1911—Fuel economy on the Chicago and Alton. 1911. (In Railway Age Gaz., v. 50, p. 1414.)

Principal dimensions and fuel consumption of Mikado locomotives.

Kinyon,

Latest developments and improvements in automatic stokers. 1911. (In Traveling Engrs. Assoc., v. 19, p. 205-288.)

Describes the Crawford, Hanna and Street automatic stokers and discusses the economy of using mechanical stokers.

Practical demonstration in fuel economy. 1911. (In Railway Age Gaz., v. 51, p. 175.)

The total amount of coal used was only 15 tons and 70 lbs., whereas the usual amount of coal used on this same run varies from 25 to 30 tons.

Randolph, V. C.

Value of practical instruction on fuel economy. 1911. (In Proc. Traveling Engrs. Assoc., v. 19, p. 77-123.)

Describes method used on the Erie Railroad.

Traveling Engineers' Association.

Benefits derived from the use of the brick arch. 1911. (In Proc. Traveling Engineers' Assoc., v. 19, p. 378-412.)

Makes the statement that the brick arch saves coal because of the better combustion and because of the baffling and retaining effect on the gases and on the light fine and combustible, which would go through flues as partly consumed coal or sparks.

Traveling Engineers' Association.

Increased efficiency of locomotives and benefits derived from chemically treated waters. 1911. (In Proc. Traveling Engrs. Assoc., v. 19, p. 316-342.)

Report of a committee.

1912—Buell, D. C.

Proper method of firing locomotives. 1912. (In Proc. International Ry. Fuel Assoc., v. 4, p. 93-140.)

On firing with coal and with oil; illustrated.

Collett, Robert.

How can the traveling engineer get engineers and firemen interested in the economical use of fuel and lubricants, maintain that interest, and the effect of lubricating methods on fuel economy? 1912. (In Proc. Traveling Engrs. Assoc., v. 20, p. 298-322.)

Recommends making test trips and shows actual records.

Collett, Robert.

Standard locomotive fuel performance sheet. 1912. (In Proc. International Ry. Fuel Assoc., v. 4, p. 42-65.)

System of accounting for showing exact amount of fuel used by each engine or crew for a given period of time.

Economical oil-burning on locomotives. (Editorial.) 1912. (In Railway Age Gaz., v. 52, p. 188.)

On the advantages of using oil for locomotives.

Goss, W. F. M.

Fuel as a factor in locomotive capacity. 1912. (In Proc. International Ry. Fuel Assoc., v. 4, p. 23-41.)

On increasing locomotive capacity, by better adaptation of fuel to the needs of locomotive service.

1912—Lloyd, T. S.
Use of anthracite coal for locomotive fuel. 1912. (In Proc. International Ry. Fuel Assoc., v. 4, p. 66-92.)
On the advantages and disadvantages of using anthracite for locomotives.
MacFarland, H. B.
Locomotive drafting and its relation to fuel consumption. 1912. (In Proc. International Ry. Fuel Assoc., v. 4, p. 143-260.)
Gives results of tests.
Traveling Engineers' Association.
Fuel economy; what relation do mechanical appliances, such as locomotive superheaters, mechanical stokers, brick arches and the handling of trains, have on the subject? 1912. (In Proc. Traveling Engrs. Assoc., v. 20, p. 88.)
Report of a committee.
Traveling Engineers' Association.
Increased efficiency of locomotives and benefits derived from chemically treated water. 1912. (In Proc. Traveling Engrs. Assoc., v. 20, p. 48-57.)
Report of a committee.
1913—American Railway Masters Mechanics' Association.
Report of standing committee on mechanical stokers. 1913. (In Proc. Am. Ry. Master Mech. Assoc., v. 46, p. 68-98.)
Considers fuel economy and increased capacity of locomotives from use of mechanical stokers.
Anthony, J. T.
Combustion in locomotive practice. 1913. (In Ry. Age Gaz., v. 54, p. 1220.)
The problem of increasing boiler efficiency.
Benjamin, C. H., and L. E. Endsley.
Tests of superheater locomotives. 1913. (In Proc. Amer. Ry. Master Mechanics' Assoc., v. 46, p. 414.)
Contains data showing increase of power of the superheater locomotive over the original locomotive when using the same amount of coal.
Buell, D. C.
Are you watching the coal pile? 1913. (In Ry. Age Gaz., v. 55, p. 221.)
A series of questions and suggestions emphasizing the necessity of giving detail attention to the fuel problem.
Collett, R.
Locomotive fuel economy. 1913. (In Ry. & Engng. Rev., v. 53, p. 537.)
Considers waste of fuel, giving various reasons and gives tests with locomotives using coal and oil.
Collett, Robert.
Locomotive fuel economy on the Frisco. 1913. (In Ry. Age Gaz., v. 55, p. 874.)
Analyzes waste of fuel, and shows saving accomplished on the Frisco during three years.
Credit due to operating department for power utilization and train movement that reduces consumption of fuel per ton mile. 1913. (In Ry. & Engng. Rev., v. 53, p. 782, 785.)
From paper read before Traveling Engrs. Assoc.
Same: Ry. Age Gaz., Mech. Ed., v. 87, p. 469.
Flagg, Samuel B.
Sub-bituminous and lignitic coal as locomotive fuel. 1913. (In Proc. International Ry. Fuel Assoc., v. 5, p. 43-69.)

1913—Methods which have been and are employed to utilize low grade fuel, in order to reduce cost of operation.

Abstracts. Engng. News, v. 69, p. 1234; Ry. Rev., v. 53, p. 530-531; Ry. Age Gaz., v. 54, p. 1178.

Fuel. (Editorial.) 1913. (In Ry. & Engng. Rev., v. 53, p. 484.)

On getting the value of fuel in work performed, advocates mechanical stokers for locomotives; very brief.

Fuel record of ten years, the reward of good management defeated by rising costs and stationary rates. 1913. (In Ry. & Engng. Rev., v. 53, p. 532.)

Graphic representation of fuel cost to move 100 tons one hundred miles, in 1902 and 1912 and comparison on basis of fuel prices in 1902. Average on 29 and on 8 railroads.

Gee locomotive stoker. 1913. (In Ry. Age Gaz., v. 54, p. 486.)

Describes stoker, developed and patented by N. E. Gee of the mechanical engineers' office of the Pennsylvania Railroad at Altoona, Pa.

Hooper, William E.

Studies of operation—the B. R. & P. 1913. (In Ry. Age Gaz., v. 54, p. 663.)

A comparison of unit costs of operation.

International Railway Fuel Association.

Report of Committee on firing practice. 1913. (In Proc. International Ry. Fuel Assoc., v. 5, p. 118-171.)

Discussion includes economy in locomotive firing.

Landon, W. B.

Fuel economy on a trunk line railroad. 1913. (In Ry. & Engng. Rev., v. 53, p. 54-57.)

Methods of saving coal by purchasing from mines nearest coaling station; by choice of loading equipment; by the kind of coal used.

Mechanical stokers from operating standpoint. 1913. (In Ry. Age Gaz., v. 54, p. 1309.)

Heavy trains are being successfully operated on four large roads by locomotives equipped with these machines.

"On the firing line;" mechanical stoking of locomotives. (Editorial.) 1913. (In Ry. & Engng. Rev., v. 53, p. 147.)

On reducing the ton-mile cost of moving freight by getting the highest value of the fuel consumed.

Parish, Le Grand.

Advantages obtained with the brick arch in locomotive service. 1913. (In Proc. Traveling Engrs. Assoc., v. 21, p. 178-223.)

States that the cost of the arch is overshadowed by fuel saving and the maintenance cost can be kept very low with proper supervision.

Roberts, Clarence, and Russell M. Smith.

Practical locomotive operation, p. 22, 83, 181. 1913. Phila., Lippincott.

Tables of composition, heat values and weights of fuels; and its combustion; also steam and coal consumption under different pressures of superheated and saturated steam; and pounds of coal per dynamometer horsepower-hour for slow and fast passenger and freight locomotives.

Results of comparative firebox tests; summary of the report of those recently conducted at Coatesville, Pa., with a brief reference to methods employed. 1913. (In Ry. Age Gaz., v. 54, p. 251.)

Gives data on fuel economy.

1913—Shurtleff, A. K.

Locomotive fuel consumption and the speed diagram. 1913. (In Proc. Amer. Ry. Engng. Assoc., v. 14, pt. 2, p. 3-20.)

Gives results of tests.

Standard locomotive stoker. 1913. (In Ry. Age Gaz., v. 55, p. 647.)

Absence of apparatus in the cab and noiseless operation are prominent features of this new locomotive stoker.

Tollerton, W. J.

Fuel economy on the Rock Island. 1913. (In Ry. Age Gaz., v. 54, p. 103.)

On the Rock Island Lines the system adopted is educational, showing the enginemen the proper method of handling a locomotive.

Wells, M. E.

Fuel economy by the engine crew. 1913. (In Ry. Age. Gaz., v. 55, p. 563.)

Brief discussion on economical cut-off; heavy slug firing versus light careful firing; overloading tanks at coal tipples.

Wood, Walter D.

Powdered fuel for locomotives. 1913. (In Ry. Rev., v. 55, p. 13.)

Coal in powdered form has replaced oil fuel in cement mills, proving cheaper; also besides being from one-third to one-half cheaper than burning coal in the regular form, it is absolutely smokeless. Both of these things recommend it at once for use on locomotives.

Woodbridge, H. C.

Fuel economy on the Buffalo, Rochester & Pittsburgh. 1913. (In Ry. Age Gaz., v. 54, p. 297.)

Describes economies effected by the use of a specially designed locomotive draft regulating damper.

1914—Abating smoke and increasing efficiency with hand firing. 1914. (In Ry. Age Gaz., v. 88. p. 458.)

Rules to increase efficiency of hand firing.

American Railway Master Mechanics' Association.

Report of Committee on Fuel Economy. 1914. (In Proc. Amer. Ry. Master Mech. Assoc., v. 47, pt. 1, p. 323-342.)

Digest of answers to questions sent out to railroads.

Boiler design in respect to heating surface. 1914. (In Ry. Age Gaz., v. 57, p. 1079.)

On fuel economy in its relation to boiler design.

Coddington, W. H.

Locomotive road tests of Schmidt superheater and brick arch, conducted by the Norfolk & Western Railway. 1914. (In Proc. Amer. Ry. Master Mech. Assoc., v. 47, pt. 1, p. 342-388.)

On locomotive efficiency and fuel used.

Economical locomotive performance on the Frisco. 1914. (In Ry. Age Gaz., v. 56, p. 1018.)

Almost a million dollars has been saved in the fuel bill, during three years, by careful supervision.

Foltz, F. W.

Economies in round house and terminal fuel consumption. 1914. (In Proc. International Ry. Fuel Assoc., v. 6, p. 281-296.)

The discussion gives results of tests.

Abstract. (In Ry. Age Gaz., Mech. Ed., v. 88, p. 355.)

Fuel instruction car on the Northern Pacific. 1914. (In Ry. Age Gaz., v. 56, p. 976.)

For three years the Northern Pacific has been giving special attention to fuel economy, with the result that the cost of fuel per gross ton mile has been greatly reduced.

Improved Hanna locomotive stoker. 1914. (In Ry. Age Gaz., v. 56, p. 792.)

A Hanna stoker of this type is in operation on a 12-wheel locomotive on the Norfolk & Western Railway and preliminary runs are reported as being very successful.

1914—International Railway Fuel Association.

Report of Committee on firing practice. 1914. (In Proc. International Railway Fuel Assoc., v. 6, p. 185-228.)

Includes a discussion on methods of firing locomotives.

Improving the locomotive fuel record. 1914. (In Railway Rev., v. 54, p. 203.)

The cost of fuel in 1912 and 1913 was about the same, but the improvement in results continued. The expense per train mile increased owing to the greater train tonnage—but less than one per cent. The expense per ton mile, however, decreased 8.5 per cent. Result appears in less ton mile fuel cost.

Kinyon, A. G.

Sizing of coal for locomotive use. 1914. (In Proc. International Railway Fuel Assn., v. 6, p. 155-165.)

On the importance of uniform size of lumps of coal in any given lot for locomotive use, also recommends sizes from which best results may be obtained.

Abstract. (In Railway Rev., v. 55, p. 9.)

Lanier, Monro B.

Pre-heating locomotive feed water. 1914. (In Proc. International Ry. Fuel Assoc., v. 6, pp. 249-273.)

On saving fuel by pre-heating boiler water; theoretical discussion and results of tests.

Abstract. (In Ry. Age. Gaz., v. 56, p. 1156.)

Locomotive performance on the Chicago Great Western. 1914. (In Ry. Age Gaz., v. 57, p. 796.)

A careful record was kept of the mileage, tons hauled, operating expenses and repair expenses; together with the amount of coal consumed.

Locomotive smoke-box cinder as fuel. 1914. (In Power, v. 40, p. 96.)

Gives results of tests.

Ludington, C. F.

Uniform methods of computing fuel consumption. 1914. (In Proc. International Ry. Fuel Assoc., v. 6, pp. 73-108.)

Gives method of fuel accounting used on the Atchison, Topeka & Santa Fé Railway.

Abstract. (In Ry. Age Gaz., v. 58, p. 1150.)

Maintenance of equipment costs, compared with locomotive fuel costs for fiscal year 1913. 1914. (In Ry. Rev., v. 54, p. 169.)

Statistics for thirty-three representative railroads; on eleven of these roads it cost more to maintain the locomotives than for all the fuel they burned, and the average tractive power was 16.67 tons. On the other roads 14.48 tons.

Plant, L. G.

Individual fuel record and fuel economy. 1914. (In Ry. Age Gaz., v. 56, p. 788.)

Outline of a method developed on a southwestern railway system where oil fuel was largely used.

Progress of the locomotive stoker. 1914. (In Ry. Rev., v. 54, p. 21,)

Reference is made to the locomotive stoker as one of the greatest of labor-saving devices, identified with railway operation.

Scott, J. R.

Operation of all locomotives with a view of obtaining maximum efficiency at lowest cost. 1914. (In Proc. Traveling Engrs. Assoc., v. 22, p. 228,)

Includes handling and firing of locomotives with a view of obtaining maximum efficiency.

Street, Clement F.

Mechanical stokers for locomotives. 1914. (In Railway Age Gaz., v. 57, p. 739.)

Essential features to be considered in designing machines for this work; increase in tonnage obtainable..

Same. Locomotive Stoker. 1914. (In Ry. Rev., v. 55, p. 545.)

Willsie, A. N.

Fuel economy on the Chicago, Burlington & Quincy. 1914. (In Ry. Age Gaz., v. 57, p. 325.)

On saving coal by proper firing up of locomotives, on overloading tanks, and on coal records.

1915—American Railway Engng. Association.

Manual, p. 521-538. Chic., 1915. Am. Ry. Engng. Assoc.

Standards adopted for tractive power of locomotives, average evaporation in locomotive boilers, locomotive resistance, etc.

American Railway Master Mechanics' Association.

Report of Committee on Fuel Economy. 1915. (In Proc. Am. Ry. Master Mech. Assoc., v. 48, p. 262-297.)

Design of locomotives, operation of superheater and instructions for firemen in relation to fuel economy.

Abstract. (In Ry. Rev., v. 57, p. 181.)

American Railway Master Mechanics' Association.

Report of Committee on Locomotive Stokers. 1915. (In Proc. Am. Ry. Master Mech. Assoc., v. 48. p. 31-57.)

On relation of fuel economy to the use of mechanical stokers.

Ballantine, N. D.

Value of a freight locomotive from transportation standpoint. 1915. (In Railway Rev., v. 56, p. 596.)

An analysis of operation costs.

Same. Real value of a freight locomotive. 1915. (In Ry. Age Gaz., v. 58, p. 885.)

Bartholomew, W. S.

Mechanical stoking of locomotives. 1915. (In Jour. Franklin Inst., v. 180, p. 253-310.)

History and description of mechanical stokers and the economical results of their use on locomotives.

Bean, G. M.

Fuel oil for locomotive use. 1915. (In Proc. International Ry. Fuel Assoc., v. 7, p. 213-231.)

Discusses advantages and disadvantages, extravagances and economies of the use of fuel oil.

Abstracts. Ry. Age Gaz., v. 58, p. 1115; Power, v. 41, p. 900; Railway Rev., v. 56, p. 572.)

Efforts at fuel economy, Rock Island lines. 1915. (In Railway Rev., v. 57, p. 354.)

Makes the statement, that a number of tests indicate that only 45 per cent. of the fuel consumed by locomotives is actually utilized in moving the train. The far greater portion of the remaining 55 per cent. is wasted by improper firing, engines standing still under steam, repairs not being made promptly and other causes.

1915—Emerson, Harrington.

Analysis of dependent sequence as a guide to fuel economies. 1915. (In Proc. International Ry. Fuel Assoc., v. 7, p. 74-118.)

Treats of wastes of coal used in locomotives; by administration; by shrinkage in quantity between purchase and use; due to poor design; to poor running, to poor firing.

Abstracts. Ry. Rev., v. 57, p. 19-22; Ry. Age Gaz., v. 58, p. 1057-59.

Fuel economy on the Great Western. 1915. (In Ry. Age Gaz., v. 58, p. 195-197.)

Methods for saving coal; and forms for reporting performance at fuel stations.

Goodwin, G. S.

Value of a locomotive. 1915. (In Ry. Rev., v. 56, p. 259.)

On the Chicago & Northwestern Ry., it was stated, the time required for cleaning fires at engine terminals has been reduced from an average of one and a quarter hours to 15 minutes by following plan of Thos. E. Adams, of S. L. S. Ry., of not shaking locomotive grates.

Hatch, M. C. M.

Factors influencing fuel economy in locomotives. 1915. (In Ry. Age Gaz., v. 58, p. 449-451.)

Effect of design, maintenance, handling at engine house, operating department, quality of fuel, etc.

Same. Railroad fuel economy. 1915. (In Ry. Rev., v. 56, p. 506.)

International Railway Fuel Assoc.

Report of Committee on relation of mechanical stokers to the fuel problem. 1915. (In Proc. International Ry. Fuel Assoc., v. 7, p. 172-212.)

The development of the mechanical stoker, its use on locomotives, states that the stoker will show fuel economy based on ton-mile performance.

Abstracts. Ry. Rev., v. 56, p. 815; Ry. Age Gaz., v. 58, p. 113.

Le Grand, J. G.

Fuel oil installations on the Grand Trunk Pacific Ry. 1915. (In Ry. Rev., v. 56, p. 828.)

Description of facilities for receiving, storing, distributing and issuing oil fuel.

Mechanical stokers on American locomotives. 1915. (In The Engineer, v. 119, p. 42, 60, 116, 163.)

On the Baltimore and Ohio Railroad, the locomotive superintendent reported that the train loads hauled by stoker-fired engines were from 5 to 10 per cent. greater than those hauled by hand-fired engines.

Plant, L. G.

Fuel and tonnage performance on the Seaboard. 1915. (In Ry. Age Gaz., v. 58, p. 405.)

Study of records which show comparative results for the system and the various operating divisions.

Preston, W. E.

Effect of properly designed valve gear on locomotive fuel economy and operation. 1915. (In Proc. Traveling Enginrs, Assoc., v. 23, p. 35.)

Gives general principles of computing the amount of coal used; and calculations applied to engines.

Pulverized fuel for locomotives. 1915. (In Ry. Age Gaz., Mech. Ed., v. 89, p. 213.)

Tests conducted under severe operating conditions have proved satisfactory; future possibilities.

1915—Robinson, W. L.

Powdered coal. 1915. (In Proc. International Ry. Fuel Assoc., v. 7, p. 17-73.)

Some of the advantages of the use of powdered coal: Ability to operate through comparatively long periods and distances; and automatic manipulation of fire.

Abstracts. (In Ry. Rev., v. 56, p. 772-76; Ry. Age Gaz., v. 58, p. 1055; Power, v. 41, p. 793; Colliery Engr., v. 35, p. 646; Scientific Amer. Suppl., v. 80, p. 139.)

Strahl,

Saving of fuel on locomotives by the use of feedwater preheating. 1915. (In Jour, Amer. Soc. Mech. Engrs., v. 37, p. 606.)

Contains table, giving data of tests.

Street, Clement F.

What the stoker has done for the locomotive. 1915. (In Ry. Rev., v. 56, p. 69.)

Mechanical stokers increase the earning power of existing locomotives and remove limitation to size of locomotives from a fuel quantity standpoint.

Same. Ry. Age Gaz., v. 58, p. 59.

Traveling Engineers' Association.

Report of Committee on advantages of superheaters, brick arches and other modern appliances on large locomotives, especially those of the Mallet type. 1915. (In Proc. Traveling Engrs. Assoc., v. 23, p. 241-278.)

Includes curves, showing possibilities of increased capacity from superheating.

Abstract. (In Ry. Age Gaz., v. 57, p. 505.)

Use of pulverized fuel for locomotives. 1915. (In Ry. Age Gaz., v. 58, p. 941.)

Outline of results from tests extending over a year.

Wallace, Lawrence W.

Locomotive coal consumption. 1915. (In Ry. Age. Gaz., Mech. Ed., v. 89, p. 617-618.)

Results of tests made by Purdue University.

Williams, J. S.

Improved performance with old-type coaling facilities. 1915. (In Railway Age Gaz., Mech. Ed., v. 89, p. 66.)

A plan has been put into effect on the Chesapeake & Ohio at Charlottesville, Va., whereby the handling of coal has been reduced from 8½ cents to 5½ cents per ton.

Wood, Arthur Julius.

Principles of locomotive operation and train control, p. 117, 217. 1915. N. Y., McGraw.

Treats of combustion and fuel economy; and locomotive ratios, average horsepower per pound of saturated steam, etc.

1916—American Railway Master Mechanics' Association.

Report of Committee on the Use of Powdered Fuel in Locomotives. 1916. (In Proc. Am. Ry. Master Mech. Assoc., v.. 49, p. 307-326.)

Contains data on fuel economy in relation to the use of powdered coal.

Anthony, J. T.

Fuel economy and boiler design. 1916. (In Ry. Rev., v. 59, p. 653-58.)

Review of details of heat utilization by the locomotive boiler.

Anthony, J. T.

Locomotive fuel economy and boiler design. 1916. (In Ry. Age Gaz., v. 61, p. 695.)

States that larger part of heat losses is due directly to furnace inefficiency; suggestions for improving practice.

1916—Corning, C. W.

Powdered coal in engine service. 1916. (In Ry. Mech. Engr., v. 90, p. 565-568.)

On fuel economy in relation to the use of powdered coal.

Felton, S. M.

Railroad fuel problem, past and present. 1916. (In Ry. Rev., v. 58, p. 718.)

On economy in handling coal for locomotive fuel.

Fuel economy on the Rock Island. 1916. (In Ry. Mech. Engr., v. 90, p. 180.) Very brief.

Fuel oil installations and equipment, Florida East Coast Ry. 1916. (In Ry. Rev., v. 58, p. 903.)

Comparative statement of fuel cost per engine mile, coal vs. oil, Florida East Coast Ry.

Huston, Harold A.

Locomotive water and coal consumption. 1916. (In Ry. Mech. Engr., v. 90, p. 69-71.)

Methods for calculating water and coal consumption under different operating conditions.

International Railway Fuel Association.

Report of the Committee on Powdered Fuel. 1916. (In Railway Age Gaz., v. 60, p. 1081.)

States that the committee is of the opinion that the effectiveness and utility of the use of fuel in powdered form has been demonstrated from the past year's development.

Kinyon, Alonzo G.

What effect does mechanical placing of fuel in fireboxes, and lubrication of locomotives have on cost of operation? 1916. (In Proc. Traveling Engrs. Assoc., v. 24, p. 65-86.)

Treats of effect of mechanical stoking, firing with oil, firing with powdered coal.

Muhlfeld, John E.

Pulverized fuel for locomotives. 1916. (In Trans. Amer. Soc. Mech.. Engrs., v. 38, p. 1043-1104.)

On the economy of using pulverized fuel on locomotives.

Abstracts. (In Ry. Rev., v. 59, p. 852; Ry. Mech. Engr., v. 91, p. 11; Railway Age Gaz., v. 61, p. 1097.)

Muhlfeld, J. E.

Pulverized fuel for locomotive service. 1916. (In Ry. Age Gaz., v. 60, p. 349-353.)

States that it affords a means of further increasing steam locomotive capacity.

Muhlfeld, J. E.

Pulverized fuel for locomotives. 1916. (In Ry. Rev., v. 58, p. 299.)

Contains chart showing comparison of thermal efficiency of electric and steam motive power, showing percentage of power delivered at the rail to 100 per cent B. T. U. in the coal and relative value of pulverized fuel for firing steam locomotives.

Power requirements in the electrification of Chicago railroads. 1916. (In Ry. Rev., v. 58, p. 197.)

Summary of train movements and coal consumed by steam locomotives in all classes of service within the area of observation.

Preparation of stoker coal. 1916. (In Ry. Age Gaz., v. 60, p. 955-956.) On the advantage of delivering prepared coal to the tender.

1916—Robinson, W. L.

Effect of mechanical placing of fuel in locomotive fireboxes on cost of operation. 1916. (In Proc. Traveling Engrs. Assoc., v. 24, p. 32-54.)

Makes the statement that locomotives are operating at a mechanical efficiency of from 85 to 100 per cent., hauling trains and effecting operating economies not possible under ordinary hand-firing conditions.

Robinson, W. L.

What effect does the mechanical placing of fuel in fireboxes and lubrication of locomotives have on the cost of operation. 1916. (In Ry. Rev., v. 59, p. 588.)

Claims that increased tonnage and increased speed are obtained by firing locomotives with mechanical appliances.

Shaw, C. C.

Difficulties accompanying prevention of dense black smoke and its relation to cost of fuel and locomotive repairs. 1916. (In Proc. Traveling Engrs. Assoc., v. 23, p. 84.)

On the prevention of smoke on oil-burning locomotives.

Sullivan, John G.

Operating conditions and fuel consumption. 1916. (In Bull. No. 187, Amer. Ry. Engrs. Assoc.)

Gives table showing pounds of coal used per engine mile in freight train service.

Abstract. 1916. (In Ry. Age Gaz., v. 61, p. 363.)

Traveling Engineers' Association.

Advantages of superheaters, brick arches and other modern appliances on large locomotives, especially those of the mallet type. 1916. (In Proc. Traveling Engrs. Assoc., v. 24, p. 107-178.)

Report of committee.

Traveling Engineers' Association.

Committee report on advantages of mechanical stoking. 1916. (In Ry. Age Gaz., v. 61, p. 795.)

Claims increased tonnage, increased speed and saving of labor.

Woodbridge, H. C.

Fuel economy. 1916. (In Ry. Mech. Engr., v. 90, p. 71-72.)

Recommends superheating apparatus, brick arches, combustion chambers, draft regulation, feed water heaters, condensers, reheaters, stokers; the selection, preparation and storage of fuel, including both powdered and liquid combustible; very brief.

Zeibel, A. G.

Weighing coal for locomotive use. 1916. (In Railway Rev., v. 59, p. 148.)

Figures showing that there are shrinkages and overruns that are clearly beyond the control of the scale inspector or the weighmaster.

1917—Anthony, J. T.

Effect of firebox design upon boiler capacity and economy. 1917. (In Proc. Railway Club of Pittsburgh, v. 16, p. 87.)

Boiler capacity and efficiency in locomotives; gives results of tests.

Anthony, J. T.

Firebox volume and boiler performance. 1917. (In Ry. Age Gaz., vol. 62, p. 841.)

Effect of increased volume on combustion and firebox evaporation; firebox vs. tube heating surfaces.

1917—Anthony, J. T.

Locomotive firebox and combustion chamber. 1917. (In Jour. Amer. Soc. Mech. Engrs., v. 39, p. 764-770.)

On the value of boiler efficiency in increasing the hauling power of a locomotive.

Anthony, J. T.

Locomotive firebox and combustion chamber. 1917. (In Ry. Rev., v. 60, p. 307.)

Data is analyzed showing the very appreciable utility of the combustion chamber and kindred means whereby the heat of the fuel employed may be utilized to the greatest possible extent.

Bartholomew, W. S.

Mechanical firing of locomotives. 1917. (In Ry. Rev., v. 60, p. 14.)

Illustrated by diagrams, showing boiler efficiency and dynamometer horsepower at different rates of firing; evaporation at different rates of combustion, and increase of earning power of locomotive as it is worked harder.

Bearce, W. D.

Conservation of fuel by railway electrification. 1917. (In Railway Rev., v. 61, p. 664.)

Table showing power consumption of electrified railroads in the United States and equivalent coal saving.

Brown, H. B.

Kindling fires in locomotives. 1917. (In Ry. Mech. Engr., v. 91, p. 332.)

Comparative cost of firing up engines at terminals.

Same. (In Railway Age Gaz., v. 62, p. 1056.)

Fuel economy in relation to reducing the cost of kindling fires in locomotives. 1917. (In Ry. Rev., v. 60, p. 701-702.)

Data on stoker installation show low maintenance cost. 1917. (In Elec. Ry. Jour., v. 49, p. 172.)

Statistics for the years 1910-1916 for mechanical stoker for locomotives.

Firebox temperature tests, Texas & Pacific Railway. 1917. (In Ry. Rev., v. 61, p. 331.)

Tests were made by J. T. Anthony. Curves show rate of combustion and evaporation, boiler horsepower and efficiency.

Fuel Department of the Rock Island. 1917. (In Ry. Age Gaz., v. 63, p. 103.)

Organization of department for proper handling and use of fuel; includes record of locomotive performance.

Good firing. 1917. (In Ry. Mech. Engr., v. 91, p. 334.)

Brief data from textbook issued by the Baltimore & Ohio Railroad for its engineers and firemen.

Griggs, H. W.

Fuel waste in standing locomotives. (Letter) 1917. (In Ry. Age Gaz., v. 62, p. 1471.)

Relative to tests on the amount of coal used in keeping locomotives alive, and in firing them up.

Hawkins, W. P.

Theory, practice and results of fuel economy. 1917. (In Ry. Mech. Engr., v. 91, p. 304.)

Saving fuel by methods of firing and handling the engine.

Influence of powdered coal on facilitiy of conducting transportation. 1917. (In Ry. Rev., v. 61, p. 31-32.)

Shows how the use of pulverized fuel in actual service will mean adaptability of locomotive to service demands.

1917—International Railway Fuel Association.

Report of Committee on Powdered Fuel. 1917. (In Ry. Age Gaz., v. 62, p. 1230-32.)

On the advantages in using pulverized fuel and practice on several railroads.

International Railway Fuel Association.

Report of special committee on fuel tests. 1917. (In Ry. Rev., v. 60, p. 702-04.)

Tests as to whether coal especially prepared as to size, when used on locomotives, was superior to mine run coal in sufficient degree to justify the trouble and expense involved in its preparation.

International Railway Fuel Association.

Report of University of Illinois fuel tests. 1917. (In Ry. Age Gaz., v. 63, p. 51-55.)

Determination of the relative value of the various grades of Illinois coal for use in locomotive service.

Langreck, A. E.

Firing engines at engine houses. 1917. (In Ry. Mech. Engr., v. 91, p. 242.)

Methods of firing used in St. Louis.

MacBain, D. R.

Fuel economy and proper drafting of locomotives. 1917. (In Railway Mech. Engr., v. 91, p. 130-132.)

States that the better proportion of heating surface to cylinder volume is responsible for a considerable waste of fuel.

Mikado type locomotive tests; Pennsylvania test plants results. 1917. (In Railway Mech. Engr., v. 91, p. 328.)

Shows coal used per horsepower hour and indicated horsepower.

Muhlfeld, John E.

Use of pulverized fuel on locomotives. 1917. (In Jour. Amer. Soc. Mech. Engrs., v. 39, p. 760.)

From actual operation of steam locomotives in regular train service the use of pulverized fuel has eliminated smoke, improved the thermal effectiveness of the locomotives, etc.

Peat powder as a locomotive fuel. 1917. (In Railway Mech. Engr., v. 91, p. 76.)

Brief details of tests made on the Swedish State Railways.

Powdered coal for the railways. 1917. (In Railway Mech. Engr., vol. 91, p. 485.)

Summary of the developments made with this grade of fuel on the railways during the past year.

Robinson, W. L.

Stoker operation on the Baltimore & Ohio. 1917. (In Ry. Age Gaz., v. 63, p. 513.)

On the economy of the use of mechanical stokers for the locomotives of the Baltimore & Ohio Railroad.

Rock Island fuel department. 1917. (In Ry. Mech. Engr., v. 91, p. 434.)

Organization for true fuel economy, cost and consumption considered.

Slifer, Hiram J.

Graphic display of individual daily fuel records. 1917. (In Ry. Age Gaz., v. 62, p. 1105.)

Graphical records of coal consumption, readily understood by the men and shows where each engineman stands.

Same. Ry. Mech. Engr., v. 91, p. 383.

Economic Value of Automatic Signals on Railroads.

1906—Peabody, J. A.

Cost of stopping trains compared with the cost of maintenance, operation and inspection of interlocking plants. 1906. (In Engng.-Contracting, v. 21, p. 49.)

The economic use of interlocking plants to increase capacity of tracks.

1909—Wilson, H. Raynar.

Power railway signaling, p. 124-125. 1909. Lond., Railway Engineer.

Discusses economy of automatic signals.

1910—Arkenburgh, W. H.

Principles governing the arrangement of automatic block signals. 1910. (In Railway Age Gaz., v. 48, p. 1422-1424.)

Considers the physical characteristics of a road and their relation to signal locations; and the relation of signals to each other.

Cars, schedules, power consumption, running tests and signals in London subways. 1910. (In Elec. Railway Jour., v. 36, p. 212.)

Signal train stop tests were made to determine the feasibility of shortening blocks, especially near terminals and cross-overs.

Latimer, James B.

Running trains against a current of traffic. 1910. (In Signal Engr., v. 3, p. 50-53.)

Describes a method of handling train movements and states: It allows of a much heavier movement for a few hours at a time than any automatic signal system and is much more economical.

Smart, V. I.

Railway signaling. 1910. (In Canadian Engr., v. 18, p. 386, 450, 506.)

The author does not favor the wholesale adoption of automatic system and considers the absolute block method of signaling as the most economical.

Speed control signals. 1910. (In Signal Engr., v. 3, p. 25-28.)

On operation of automatic signals on the New York subway; graphic comparison of station capacity with and without speed control signals.

Van Zandt, J. G.

Scientific location of distant signals. 1910. (In Signal Engr., v. 3, p. 61-62.)

Discussion of effect of physical characteristics upon proper spacing.

1911—Arkenburgh, W. H.

Arrangement of automatic block signals. 1911. (In Signal Engr., v. 4, p. 296-300.)

Scientific treatment of principles involved with a graphical solution of spacing problems.

Conditions governing track section lengths. 1911. (In Signal Engr., v. 4, p. 100-104.)

Automatic signals, a study of how they are affected by block lengths, the kind of system used and other conditions.

Cost of automatic block signaling. 1911. (In Signal Engr., v. 4, p. 412-16.)

Figures for making quick estimates and checking construction; taken from averages of a number of installations.

Estimated cost of automatic block signaling. (Letter) 1911. (In Signal Engr., v. 4, p. 398.)

Compares cost of installation of automatic and non-automatic signals.

Thurber, Guy P.

Conservation of human life in steam and electric railroad travel. 1911. (In Proc. Railway Club of Pittsburgh, v. 10, p. 98-146.)

Shows number of accidents which might have been avoided had an automatic train control system been in operation; and describes the Gray-Thurber system.

1912—Latimer, James B.

Automatic block signaling for single-track railways. 1912. (In Engng. News, v. 68, p. 62.)

Describes the "absolute-permissive" (A-P) automatic block signal system of the C., B. & Q. R. R. and suggests that if this proves a success, that single-track railway may be operated by automatic block signals only, and a vast amount of dispatching cut out.

Latimer, James B.

Cost of railroad signal protection. 1911. (In Engng. & Contracting, v. 35, p. 689-690.)

Gives detailed costs of automatic block signals.

Observations on the economics of block signaling. 1913. (In Signal Engr., v. 6, p. 180, 252.)

States that it has been proved that signals are more economical because they enable more trains to be run on a given track in a given time, but there is a lack of data on how many additional ton miles are carried over a division.

Peabody, J. A.

Automatic control of trains. 1913. (In Signal Engr., v. 6, p. 390-392.)

Development of the subject showing particularly the effect of automatic devices on the capacity of a road.

1913—Rudd, A. H.

Truth concerning automatic stops. 1913. (In Signal Engr., v. 6, p. 164-168.)

Contains diagram, showing present conditions and effects of using automatic stops.

1914—Anthony, C. C.

Controlled manual block for opposing movements. 1914. (In Railway Age Gaz., v. 57, p. 475.)

A short two-track freight railroad in New Jersey, fulfilling the functions of a three-track line.

Arkenburgh, W. H.

Economics of railway signaling. 1914. (In Signal Engr., v. 7, p. 276, 341, 358.)

Practical and theoretical requirements in the arrangement of block and interlocking signals.

Automatic train-stop or train-control systems. 1914. (In Engng. News, v. 71, p. 855.)

On the advisability of using automatic train stops.

Baxter, W. M.

Operating capacity of single-track divisions. 1914. (In Railway Age Gaz., v. 56, p. 869-871.)

On the advantages of automatic block signals, and study of physical limitations in single-track operations.

Same. (In Signal Engr., v. 7, p. 146-148.)

Circuit requisites for single-track automatic block signaling. 1914. (In Railway Rev., v. 55, p. 441-445.)

Recommends double control as against single control; the use of a siding overlap; and placing of outgoing signals from passing sidings at the fouling point instead of beyond the main switch.

Correct theories of automatic block signal construction. 1914. (In Signal Engr., v. 7, p. 337.)

On advantages and improvements in automatic block signaling.

Economics of block signaling. (Editorial.) 1914. (In Signal Engr., v. 7, p. 160.)

Discusses the value of signals as a means of promoting efficiency and economy.

Railway Signal Association.

Economics of labor in signal maintenance. 1914. (In Jour. Railway Signal Assoc., 1914, p. 13-14.)

Advocates co-ordination of division forces in signal construction work, because while some of the work is special, much of it is such as other departments are familiar with.

1914—Some observations on the economics of automatic block signaling. 1914. (In Signal Engr., v. 7, p. 166-167.)

Amount of money saved in train operation on the Susquehanna division of the Erie by the use of automatic signals is, on a conservative estimate 20% on initial investment and 25% on total cost of the signals; also gives data for other railroads.

Arkenburgh, W. H.

Economics of railway signaling. 1915. (In Signal Engr., v. 8, p. 203, 281.)

Selection of signal system which will facilitate movement of maximum number of trains, and effect of use of auxiliary apparatus on capacity of line and economy of operation.

Automatic block signals for single-track railways. 1915. (In Engng. News, v. 74, p. 344-345.)

On the use of automatic block signals, to save double-tracking railroads.

Railway Signal Association.

Capacity of single track. 1915. (In Jour. Railway Signal Assoc., 1915, p. 326-338, 532-534.)

On signaling of single track and the effect of the number and location of passing sidings.

Railway Signal Maintenance.

Economics of signal maintenance. 1915. (In Jour. Railway Signal Assoc., 1915, p. 325-326.)

Because the main controlling power of signal apparatus is electrical, and because the special training required is so different, the Committee does not recommend as a means of obtaining economy and efficiency, a combination of signal and track forces.

Railway Signal Association.

Single-track automatic signaling. 1915. (In Jour. Ry. Signal Assoc., v. 20, p. 100-108.)

Discussion on fundamentals of operation.

Economics of labor in signal maintenance. 1916. (In Railway Rev., v. 58, p. 791-792.)

On handling of signal forces.

Railway Signal Association.

Capacity of single track; location of passing sidings. 1916. (In Jour. Railway Signal Assoc., 1916, p. 223-234.)

How automatic block signals change conditions in regard to the reduction in capacity and delay to freight trains, caused by a high-speed train when based on the use of manual block.

1916—Railway Signal Association.

Exposition of the three schemes of signaling adopted in 1913 1916. (In Jour. Railway Signal Assoc., 1916, p. 19.)

On low speed and medium speed for trains and layouts permanently restricting speed.

Shaver, A. G.

Cost of installation of automatic train control in connection with automatic block signals. 1916. (In Railway Rev., v. 59, p. 341.)

An attempt to estimate the use and cost of automatic train control.

Shaver, A. G.

Economics of railway signaling. 1916. (In Railway Rev., v. 58, p. 46-48.)

Shows how signals are an important although sometimes an indefinite factor in the economical and efficient operation of the railroad, outside of the safety functions performed.

Economics of Car Loading.

1912—Strombeck, J. F.

Freight classification. a study of underlying principles, p. 41, 68. 1912. Boston, Houghton.

Contains brief data on car loading.

1913—Capacity and movement of freight cars. (Editorial) 1913. (In Iron Age, v. 92, p. 1225.)

Statistics of the Interstate Commerce Commission of interest in relation to the movement for the heavier loading of freight cars.

Car loading efficiency. 1913. (In Railway & Engng. Rev., v. 53, p. 129-130.)

Statistics showing advantages which would have been derived from increasing average freight car load, based on operation of the Chicago & Northwestern Railway.

Heavier loading of cars: Why has the increase in capacity of freight cars failed to accomplish a proportionate increase in the average load? 1913. (In Railway & Engng. Rev., v. 53, p. 996-998, 1024-26.)

Recommends the abandonment of the exclusive use of the two-base units, the carload and the less-than-carload rate and establishment of a graduated system of rates.

Increasing the loading of cars. (Editorial) 1913. (In Railway Age Gaz., v. 55, p. 810.)

Advocates graduated minimum weights for freight cars should be adopted by the railroads.

Studies of operation—the C. B. & Q. 1913. (In Railway Age Gaz., v. 55, p. 85.)

On increase in traffic and train load; a growth in freight traffic from 1901 to 1912 of 98.3% was handled with a decrease of 9.8% in train miles.

Townsend, J. F.

Heavy loading of cars. (Letter) 1913. (In Railway & Engng. Rev., v. 53, p. 959-960.)

Measures taken by subsidiaries of United States Steel Corporation toward building up heavier carloads.

Wilson, Gordon.

Economy of capacity of loading from the shipper's point of view. 1913. (In Railway Age Gaz., v. 55, p. 830.)

A plea for capacity loading, twelve months in the year.

1914—Heavier loading of cars. 1914. (In Iron Age, v. 93, p. 750.)
Two tons more in a carload would save one road $2,500,000 in a year.

Heavier loading of cars. (Editorial) 1914. (In Railway Age Gaz., v. 57, p. 1033.)
Very brief reference on the economy of shipping full carloads.

Spears, Charles F.
Possibility of future increases in train loads. 1914. (In Railway Age Gaz., v. 56, p. 828-830.)
The views of twenty-eight railroad presidents are given.

Studies in operation—St. Louis & San Francisco. 1914. (In Ry. Age Gaz., v. 56, p. 501.)
Remarkable results from an educational campaign for heavier freight trains and better car loading.

Townsend, J. Fred.
Graduated railroad transportation rates. 1914. (In Iron Age, v. 93, p. 1526-27.)
Question of larger freight cars, heavier loading and a scale of rates to encourage good loading.

Townsend, J. Fred.
Increasing the car load. 1914. (In Ry. Age Gaz., v. 57, p. 574.)
States that "during the last 20 years the maximum freight car capacity has increased only 100%, while the locomotive capacity during the same period has increased 400 per cent"; suggests methods of increasing car loads.

1915—Increasing efficiency as indicated by larger train loads. 1915. (In Ry. Age Gaz., v. 59, p. 1041.)
Twenty-eight important roads show increases in their tonnage per freight train during the year 1915; the average gain for these roads being twenty-two tons per train.

1916—Campaign to increase car loading on the Chicago & North Western. 1916. (In Ry. Age Gaz., v. 60, p. 687-689.)
As the loading of carload freight is done by the shipper and is not under the direct control of the railroads, this campaign has necessarily consisted mainly of work among the shippers.

Car loading on the International & Great Northern Ry. 1916. (In Railway Rev., v. 58, p. 501.)
On increasing the tonnage per car in order to decrease the car shortage.

Townsend, J. F.
Heavier loading of cars. 1916. (In Railway Rev., v. 58, p. 488.)
Relation of car loading to car shortage and how shippers can, by heavier car loading, reduce the number of cars required and contribute to the net earnings of the railways.

Turner, Walter V.
Vital relation of train control to the value of steam and electric railway properties. 1916. (In Jour. Franklin Inst., v. 182, p. 428.)
Discusses traffic capacity factors and their limitations for maximum traffic; this includes car loading, train length and maximum speed.

Brown, Stephen H.
Secure the co-operation of the men. 1917. (In Railway Age Gaz., v. 63, p. 67.)
On car loading.

1917—Handling of less-than-carload freight in warehouses and on platforms on the M. K. & T. Ry. 1917. (In Ry. Rev., v. 61, p. 255.)
Critical Review of facilities and methods on the Missouri, Kansas & Texas Railway system; taken from report of investigation.
Increased loading of fruits and vegetables. 1917. (In Railway Age Gaz., v. 63, p. 350.)
Suggestions showing how increased car loading will eliminate the car shortage.
Increasing the train load. 1917. (In R. R. Herald, v. 21, p. 211.)
On increasing train load by better car loading.
Increasing the train load. 1917. (In Ry. Age Gaz., v. 62, p. 299.)
On the Norfolk & Western Railway, it required an increase of less than 15% in train miles to take care of an increase of over 75% in the freight handled.
Noble, H. S.
Loading trains for through movement. 1917. (In Railway Age Gaz., v. 63, p. 347.)
On car loading.
Reddig, H. F.
Loading cars intelligently. 1917. (In Railway Age Gaz., v. 63, p. 459.)
On increasing the revenue tons per freight mile where no reduction is to be made in the grade line or increased capacity of motive power or equipment.
Shaughnessy, E. H.
Buy a carload. 1917. (In Railway Age Gaz., v. 63, p. 457.)
One way to increase the train load without expenditure for grade reduction, and larger locomotives.
Simmer, M. A.
Train loading means car and locomotive loading. 1917. (In Railway Age Gaz., v. 62, p. 1401-1403.)
Increasing freight train load increases the capacity of the line, making unnecessary additional main tracks.
Smart, A. G.
Attention to details brings results. 1917. (In Railway Age Gaz., v. 62, p. 1404.)
On car loading.
Striving to make one freight car do the work of two. 1917. (In Railroad Herald, v. 21, p. 187.)
On car loading.
White, J. Lowell.
How one road increased its train load. 1917. (In Railway Age Gaz., v. 63, p. 201.)
The methods described are those adopted by the Atlantic Coast Line.
Wildman, C. B.
Some of the remedies. 1917. (In Ry. Age Gaz., v. 63, p. 65.)
On car loading.
Williams, H. T.
Make the despatcher responsible. 1917. (In Railway Age Gaz., v. 63, p. 457.)
Statement, showing results that can be obtained in decreasing the train and locomotive miles by increasing the engine load.
Winfield, Edward.
All departments can help increase train loads. 1917. (In Railway Age Gaz., v. 62, p. 1403-04.)
Suggestions on car loading.

REPORT OF COMMITTEE XIV—ON YARDS AND TERMINALS.

E. B. Temple, *Chairman;*
W. G. Arn,
H. Baldwin,
Miles Bronson,
G. H. Burgess,
A. E. Clift,
L. G. Curtis,
H. T. Douglas, Jr.,
A. C. Everham,
E. M. Hastings,
H. W. Hudson,
D. B. Johnston,
B. H. Mann, *Vice-Chairman;*
F. E. Lamphere,
H. A. Lane,
A. Montzheimer,
H. J. Pfeifer,
S. S. Roberts,
C. H. Spencer,
E. E. R. Tratman,
E. P. Weatherly,
W. L. Webb,
A. J. Wharf,
J. G. Wishart,
Committee.

To the American Railway Engineering Association:

The Committee on Yards and Terminals begs to submit the following as its nineteenth annual report:

The Board of Direction outlined the work of your Committee for 1917 as follows:

(1) Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

(2) Report on handling of freight in double-deck freight houses and cost of operation. Also report on handling of freight by mechanical means.

(3) Continue study of typical situation plans of passenger stations and methods of their operation.

(4) Report on classification yards.

Mr. W. G. Arn of our Committee is somewhere in France with an Engineering Regiment; Mr. H. W. Hudson of our Committee is somewhere in France on the Staff of Director General of Transportation; Mr. F. E. Lamphere is with the Quartermaster's Department, engaged in the construction of cantonments and warehouses in this country.

The several Sub-Committees that are continuing investigation of the subjects have collected data during the year. The General Committee held a meeting at the William Penn Hotel in Pittsburgh on November 21st, at which reports of the Sub-Committees were submitted. A second meeting of the General Committee was held at the office of the Association in Chicago on December 7th. On account of the extraordinary demands created by the war upon the yards and terminals of the railway systems of the Continent, it has been agreed by the Committee this year to make for presentation to the Association a detailed study of possible improvement of existing yards. As a second subject, we bring up to date the co-operative work on Scale Specifications of our Committee and the

Sub-Committee on Weighing of the American Railway Association. It has not been considered desirable this year to submit further data on the comparative statement of the operation of hump and flat yards.

(1) REVISION OF MANUAL.

The Committee recommends no change this year in the Manual.

(4) WAR EMERGENCY YARD IMPROVEMENTS.

The Committee this year under the circumstances and following Article 1, Section 2 of the Constitution, which reads in part:

> "The advancement of knowledge pertaining to the * * * economic operation of railways,"

attempts to spread before the Association Membership a digest in the form of a catechism to bring out from the Manual such hints as it contains as to

> The improvement in detail of the yards we have and the elimination of slight defects which hinder the steady operation of yard service or cause detentions which, small in themselves, become serious in the aggregate.

From extensive correspondence by the Committee, this form of handling has appeared to be of two-fold benefit; (1) to the members of the Association themselves, and (2) as a means of collecting information as to individual yards from railway officers or employees who may not be closely following the work of the Association. The Sub-Committee held several meetings and as a first result sent out the following circular on October 25th to approximately 225 Engineering Operating Officers represented in the Association:

GENERAL.

1. Your Committee points out that while there are certain general principles governing the design of yards, yet each yard constitutes a separate problem with its local conditions of design and operation.

2. Improvement in detail of any one yard, therefore, will be governed largely by these conditions rather than by general principles.

3. For this reason it is suggested that each railway should consider the improvement in detail of its individual yards.

4. Reconstruction and alteration of yards on a large scale is impracticable at this time on account of press of more important business, the lack of money and the shortage of material and men, to say nothing of the undesirability of assigning engines and cars to work of this kind.

5. Of greater importance at the present time is the improvement in detail of the yards we have, and the elimination of minor defects or features which hinder the steady operation of yard service or cause detentions which, small in themselves, become serious in the aggregate.

6. Real improvement of this kind can be made only by a careful study of the yard and its operation. This should include consultation, not only with the local officials, but also with the yardmen and switchmen, as they have the details of the service at their finger-ends and know where and what are the weak points.

7. It is the thought of the Committee that great good could be effected on many railways by the appointment of a small Committee, detached from all other duties, to go over the line and make a detailed study of the operation of the larger terminal and division yards for the purpose of determining instances where minor or simple changes or additions will facilitate or cheapen operations to an appreciable extent.

8. The Committee should preferably be composed of a representative of the Engineering Department, who has had experience in the designing of yards and manifested a thorough conception of yard requirements, and a practical yard man, a yardmaster or perhaps a yard conductor who has given evidence of a live understanding of yard operations. Such men are to be found on every railway.

9. This Committee should be instructed to approach every case with an absolutely open mind. Its recommendations should be made with the expectation that the improvements recommended will be made promptly.

10. Knowledge of improvements of this kind in one yard may be helpful and suggestive in the improvement of other yards and on other railways, and it is desirable that information as to such detail improvements should be presented to the Yards and Terminals Committee

11. Information that will be of common interest will be embodied in the report of the Committee to the Association.

12. A certain classification of yards, according to their purpose, should be recognized.

OCEAN TERMINALS.

13. Apart from the general yard problem, ocean terminals constitute a special class and, under present conditions, present an emergency problem that must be met in a large way, requiring the construction of extensive additional facilities that may be more or less of a temporary nature.

14. Extra detentions may be caused by lack of vessels to receive the freight. This results in holding up the equipment with consequent congestion of the terminal tracks. Much can be done in such cases by the provision of warehouses and storage facilities for foreign shipments held awaiting vessels, thus releasing cars and clearing the terminal tracks.

15. An entirely different and unusual situation is involved in the handling of military equipment. At shipping ports this traffic may be too great to be handled in existing yards, and it may be desirable to establish separate yards where men, stock, supplies and munitions can be unloaded and held awaiting shipment. The layout of such yards requires special consideration, and it will be of interest to secure information as to what has actually been done in this direction.

Up to November 20th replies were received from about five per cent. of the officers to whom the circular was addressed. These replies all held that the suggestions of the Committee were practical and good, but that, owing to the present traffic conditions and to the inadvisability of taking competent men from their duties, it was deemed impracticable at this time to undertake the investigation suggested by the Committee.

Your Committee would point out, however, that in present emergencies of railway operation such an inquiry and such yard improvements as are suggested in this report are of direct and immediate importance, and their value depends very largely upon immediate action. It is entirely probable that some of the officials who have not replied are considering the suggestions seriously, and have possibly made arrangements to carry these out and feel it necessary to defer reply to the circular until they have obtained results.

The Yards and Terminals Committee is a large one, which has representatives from all sections of the United States. They are men of experience and have kept in touch with the various developments of railroad yard work. They realize the unusual conditions existing on railroads at the present time and know the inadvisability of making any extensive changes or even any moderate changes which will interfere with yard operation or require any considerable outlay of money.

But, from their personal experience, they are convinced that in many yards, especially the older ones which were less thoughtfully designed and enlarged, there are many minor changes which may be made with practically no interference with traffic and at nominal cost, and which will materially increase the efficiency and capacity of these yards.

At a second meeting of the Committee held December 7th, the whole subject was again reviewed, because of the present congested conditions. From the experience of its individual members and from the replies received to its circular, the Committee is convinced that actual benefits will result from certain slight changes in yard facilities. The changes suggested are familiar to all yardmen, but the Committee emphasizes them by presenting them in the following question form:

The principle of good yard design comprises three fundamental requirements, which are:

(1) To get the train into the yard and clear the main line.

(2) To classify the cars in the yard, which includes all intrayard movement, of cars and engines.

(3) To get the train out on the main track and clear the yard.

With these principles in mind, the following suggestions arise in the form of direct questions:

1. Can you extend your yard lead or construct one adjacent to the main track of sufficient length to hold a maximum train, so that an arriving train can quickly clear the main track before entering the yard and a departing train may quickly clear the yard before going out on the main track? If trains arrive or depart at close intervals, can a second lead track be constructed? These lead tracks are sometimes called receiving or departure tracks.

2. Are your connections between
    (a) Main tracks
    (b) Lead tracks
    (c) Drill tracks (or tracks on which switch engines operate)
    (d) Yard tracks, so arranged that trains may enter and leave the yard with a minimum of interference with switching movement?

3. Are your yards so arranged and have you sufficient running tracks so that you can take a transfer from one end of the yard to the other without interfering with the usual switching? Could the efficiency and capacity of the yard be increased by the enforced holding open of a track (otherwise used for holding cars) as a running track?

4. Are your crossovers so arranged as to give the least interference with switching and the greatest elasticity of movement, or can additional crossovers be put in to secure these results? Where the number of tracks in classification yard is fixed and where the number of classifications has increased, can connecting crossovers be so located between these classification tracks as to reduce the number of movements for the required classification?

5. If your receiving or departure tracks are too short, can you lengthen one track in each yard in order to take care of the maximum train?

6. Are your caboose tracks so located and have they such connections at each end that cabooses may be handled with the least amount of switching service?

7. Can you take the engine off your train and get it to the roundhouse, and also get it from the roundhouse to an outbound train without materially interfering with switching?

8. Can you facilitate handling road engines by providing a "tie-up," "parking" or "engine storage" track near the engine terminal?

9. Can your yard engines clean fires and take coal, sand and water without delay? Do you change switching crew where engine works, or do you send the engine to "tie-up" track for change?

10. Are the trackmen given opportunity to repair busy tracks? Are you having yard derailments or delays due to bad tracks, particularly at curves, switches and frogs?

11. Can you quicken movement of trains through the throats of the yard by putting on switch tenders at these points during the busiest part of the day?

12. Is the present assignment of tracks in the yard for the various operations the proper one?

13. Can you in any case improve the yard movement by reversing the movement of traffic?

14. Can you facilitate switching by making inexpensive changes in grade in yard at any point? If you are operating a hump, can you change grades of the hump and facilitate switching?

15. Are you using the cut-list system in hump yards to avoid confusion in classification and to fix responsibility for damage while handling cars?

16. Can you improve switching conditions after dark by installing lights?

17. Are you handling any cars through the yard with more movements than are absolutely necessary?

18. Could you facilitate weighing and lessen interference with other switching by rearrangement of existing connections or by the addition of other connections to the scale track?

19. Are your bad-order and repair tracks so located as to require the least amount of engine service?

20. Can you lessen the cost of icing cars by changing the track layout?

21. Are your car inspectors properly organized, and so located and equipped that they do not delay switching or departure of trains?

22. Can some terminal delays be avoided by the installation of compressed air lines to charge the brake equipment of trains and avoid the delay of pumping air on train after engine is coupled on?

23. Are your outgoing trains delayed "Waiting for Orders"?

24. Is your yard or road service hampered due to lack of proper telephone facilities or other means of communication?

25. Is the time of switching crews wasted by faulty handling of waybills?

If any railroad, after consideration of the above questions puts any of the suggestions into effect, the Committee will appreciate a report of the changes made and the benefits derived.

The Committee will tabulate and publish these reports without naming the railroad reporting. This will give not only the Committee, but the railroads at large, the benefit of the work done, and it may be pointed out that this is one of the important purposes of the Association.

The Committee will also appreciate reports from any railroad which has accomplished results along these lines by adoption of changes other than those suggested by the questions of the Committee.

Following are some of the replies received in answer to the Committee's circular:

(A) What is recommended by the Sub-Committee is in line with the policy adopted by this Company years ago. We have not, however, carried the matter forward to the extent of appointing a committee for the purpose of giving these matters exclusive attention, nor would we consider doing so at this time, for the reasons:

(1) We have not sufficient available men to take care of any radical changes.

(2) Under present conditions, such changes would seriously interfere with yard operations.

(3) Minor defects can be located from time to time and adjusted as opportunity serves, without the aid of a committee exclusively engaged in the study of yard conditions, etc. (See Note A.)

Committee's Note: (A) Your Committee would note, however, that one cause of trouble is that such defects are often overlooked and neglected and are not adjusted when opportunity serves, because there is no one special authority to take charge and see that they are adjusted.

(B) A committee was appointed something over a year ago having in view substantially the recommendation covered by this abstract in question, the committee having special training in the transportation department and aided locally by transportation and engineering officials in each instance. The purpose at that time was to anticipate the enforcement of the Eight-Hour Law, which necessitated the utmost economy in operation and considerable expenditure in order to obtain same. After going over the entire property, the committee was dismissed, and at the present time no committee, specially appointed for that purpose, is in existence and no further report is therefore available at this time (see Note B).

Committee's Note: (B) It will be of interest to have particulars of the report and the improvements made or suggested for incorporation in the report of the Yards and Terminals Committee.

(C) You will find such a plan as the Committee proposes outlined in the Railroad Gazette for January 4th, 1901, page 1, and the result of the yard design carried out in accordance therewith is discussed in the article.

(D) I agree thoroughly that we would be very much benefited by the study, but we are finding it so hard to obtain both yardmasters and engineers to attend to our legitimate needs that it is almost impossible to dispense with the services of any of our good men long enough to put them on such a committee, and I am very much afraid that we will not be able to handle the study during the present business conditions. I am very sorry, as I should have liked to co-operate with you as fully as possible, but it is simply out of the question.

(E) I would heartily approve the report of this Sub-Committee as being the proper method to pursue at the present time. It is impossible to take up the question of the larger revision and overhauling of railroad terminals with conditions as they are at present, but in my opinion there is hardly a railroad in the United States that cannot be improved very materially by going over it carefully and approving the small expenditures in the way of crossovers, changing of switches, shortening or lengthening of certain tracks and the arranging of facilities for car repairs and facilities for loading and unloading at team tracks.

Service in a great many yards at the present time is made very slow and expensive on account of lack of small changes and a few additions and betterments. If these matters could be gone over by the Committee as suggested, there is no doubt but great benefit would result (see Note E).

Committee's Note: (E) This reply exactly endorses the position taken by the Committee.

(F) I think that the report of the Committee in general is quite correct. Owing to the demoralized condition of labor due to many cantonments being built here by the Government we do not propose to do any more work than is absolutely necessary. We have some terminal yards that need attention, but they are involved in a Union Depot scheme which makes it impossible to do anything until some kind of an agreement is reached between the interested parties. Therefore, for the present there will be no need of our appointing a committee to investigate our terminals.

(G) I have carefully gone over this report, and have taken up same with our Vice-President and General Manager. He agrees with me that the plan outlined is a good one, but that at this time, due to abnormal conditions, it is not practicable to detach any employes from their present assignments in order to make a study of the conditions. We expect to do so, however, as soon as conditions permit.

(H) I would advise that in my judgment the recommendations are most excellent and timely. I have recommended to our management that we follow out these recommendations by appointing a committee of two representatives, as suggested, to investigate conditions. In case my recommendation is approved and adopted, I will advise you further.

(J) I thoroughly agree with the principles stated in the abstract of the preliminary report of Sub-Committee of the Yards and Terminals Committee. They are clearly stated and right to the point, especially items Nos. 1, 5 and 6.

As to the committee personnel mentioned in item No. 8, I would suggest the addition of a trainmaster or other official who would have a general knowledge of the road, with authority to designate at the originating yards the make-up of trains with a view of reaching their destination in the minimum of time by being kept out of the detail work of the succeeding yards and be received and held on designated tracks only a sufficient length of time to change power and crews. This should have a distinct effect on the "Improvement of Traffic Movement."

The report contains the most comprehensive and clean-cut idea of the difficulties in yard operation and the required remedies therefor that I have ever seen, and that anything done along the lines suggested would result in improvement. Under present traffic conditions is just the time when many of the improvements suggested would be of especial benefit.

One other thought which in nowise detracts from improving to the utmost any yard layout, viz.: it is a well-known fact that much of the delay in freight movement is due to yarding, and to improve this condition should be the object of the originating classification so that at subsequent divisional run yards as many trains as possible could be run in on sidings parallel with and adjacent to the main track, where power and crews could be changed and the trains proceed with a minimum delay. This is hinted at in question No. 17 of the revised report.

My experience is that too many yard plans are prepared in the division office and from a divisional viewpoint, which results in a duplication of shifting and facilities, and would suggest the addition to the Committee recommendation in paragraph 8 that one of the representatives should have a knowledge of the operation of the entire road and facilities so as to eliminate duplication of work.

On tidewater terminals, I believe an investigation will show a very great saving in the cost of handling by providing storage warehouses and thus saving a large amount of trackage and underlying property, as well as promptly releasing the cars.

(K) I give below a list of comparatively slight changes or expenditures that were made to speed up the movements at yards and other points along the line:

(1) An expenditure of $200.00 for connecting the stub end of a track enabled pusher engine to get to its train without fouling of other movements.

(2) Change in location of caboose track permitted dropping of cabooses to train without delay.

(3) Car repair yard connected to switching lead avoided former delay in switching out crippled cars.

(4) The construction of 225 feet of track at receiving yard cleared up a point of congestion.

(5) Change of crossover from trailing to facing in double track territory where freight trains only are operated facilitated running trains around each other and expedited movement.

(6) A crossover from main track to center of long siding enabled local freight trains to reach freight house located on outside of siding with very much less interference with use of siding.

(7) Installation of auxiliary yard office at northbound yard greatly facilitated departure of trains. Cost was merely for small building and two telephones.

(8) Use of small engine to furnish steam for thawing out coal in severe weather expedited fueling of locomotives.

(9) Construction of Wye for turning pusher engines avoided great congestion and delay at turntable and saved considerable distance in run of pushers.

(10) Introduction of a crossover one mile from end of a three-track system provided a passing or holdout siding and facilitated movements.

(11) Moving of a yard limit board facilitated movement where junction of two main lines was a considerable distance from main terminal.

(12) Moving of telegraphers from one interlocking tower to another nearer the point of departure from yard avoided holding main track while getting orders.

(13) Installation of scale on hump avoided flat switching and greatly facilitated movement.

There is probably only two of these improvements that cost over $1,000.00—the new Wye track mentioned and the new scale on the hump—and some of these changes were made at practically no expense or at such trivial expense as not to be worthy of consideration.

I am quite sure that on nearly all of the railroads of this country careful observation of the workings at the different yards by men not directly connected with yard operation will result in making changes that will be of benefit.

(L) (1) Elevated our switching leads at both ends of yard so that we have the assistance of gravity in dropping cars into the yard.

(2) On one of our yards which was very wide and we were confined to a comparatively narrow neck in reaching the yard, we lapped No. 7 turnouts on the lead so that there were two frogs for each track instead of one. While this added some expense to the work, it greatly facilitated the switching, as it brought the switches closer together and enabled us to make the switching lead with an angle of 1 in 3½ instead of 1 in 7, as would be the case if switches were not lapped.

(4) SCALE SPECIFICATIONS AND RULES.

Our Sub-Committee on Scales this year has continued co-operation by correspondence and meetings with the Sub-Committee on Weighing of the American Railway Association, the Federal Bureau of Standards and with the Scale Manufacturers' Association and recommend the following Track Scale Specifications and Rules.

The Committee on Iron and Steel Structures of our Association has been asked to approve the data on scale superstructures contained in Tables 1 and 2 under "Capacity," Article 3, Section (e). Certain differences between these specifications as now submitted and those of the American Railway Association as recently published will be taken care of by the American Railway Association, we hope, at the time their specifications are next reprinted.

The Committee also submits as information the rules adopted by the American Railway Association on Equipment for Testing Track Scales and on the subject of Scale Test Cars. Your Committee has not as yet made a study of these questions and is, therefore, not in a position to recommend the adoption of these additional rules and specifications by printing them in our Manual.

TRACK SCALE SPECIFICATIONS AND RULES.

The following recommendations are made with the view of setting an ultimate standard to which railroads generally may work, but are not intended to condemn scales, methods of installation or reinstallation of scales, now in service, which come within the sensibility and tolerance prescribed in Section 2 and respond to tests as prescribed in Section 10.

1. General.

The selection of a track scale should be based on the following principal considerations:

(a) Maximum loads to be moved over the scale for weighing or otherwise, the spacing of the supporting axles and the concentration of weight thereon.

(b) Length of wheel base of cars or other equipment to be weighed.

(c) Whether cars are to be weighed spotted or in motion.

2. Scale Design.

(a) Scales should be so designed that, when the load is applied to the main supporting levers, the oscillation of the platform will not displace the bearings at points of contact on the knife-edges.

(b) The vital parts should be readily accessible for cleaning, inspection and adjustment.

(c) Like parts of a scale of given manufacture, type, length and capacity, should be interchangeable as far as practicable.

NOTE:—Some roads specify that scales of the same type, length and manufacture, be interchangeable on foundations, while other roads specify further that scales of the same type and length, but of different manufacture, be so interchangeable.

(d) Scales should be constructed preferably in not more than four sections.

(e) In scales of more than two sections, either of two methods of designing weigh-bridge girders may be employed.

First:—Girders of continuous type.

Second:—Non-continuous girders of such design of bracing and of joints over center of bearings as will admit of flexure vertically without derangement of sections.

(f) Practical means of adjustment, such as wedges, etc., should be provided to secure proper distribution of load on scale at points of support.

(g) To insure parallelism of pivots, machined ways should be provided where nose-irons engage the levers. The nose-irons should be designed for movement by a non-corrosive machine screw or other mechanical device, and, in addition to this, each nose-iron should be clamped in position by at least two binding screws or bolts, or an equivalent locking device.

The use of set screws which make indentations in the levers is undesirable, on account of such indentations making it difficult to secure nose-irons in exact position when slight adjustments are made.

The normal position of nose-iron as determined by shop sealing should be marked by a line or some equally effective method.

(h) Levers should be provided with leveling lugs, upon which a level can be placed to establish the horizontal position of the levers. The faces of these lugs should be machined in line with the contact edges of the two end pivots or knife-edges. They should be as far apart as practicable and not closer together than ten (10) inches.

(i) When scale design requires the use of checks, either the rod or the bumper type may be used. They should be located as nearly as practicable at the top plane of the weigh-bridge girders. Check-rods should be horizontal when the average load is on the scale. Check-rods should be adjustable and set without initial strain.

(j) Beams should be so designed as to weigh all loads on main and fractional bars without use of hanger weights. The main bar of beam should have not more than six (6) notches to the inch, each notch to represent one thousand (1,000) pounds. Fractional bar should be graduated to fifty (50) pound sub-divisions, with not more than four sub-divisions to the inch.

A shoulder should be provided on all beams to prevent the poise traveling back of the zero graduation.

Where the scale is not equipped with a full-capacity beam, the maximum capacity must be clearly and permanently placed on the scale, where it may be easily seen. To facilitate accurate reading of scale beam, symmetrically indicating poises are desirable.

Beams should be fitted with a pointer, to be used in connection with a fixed pointer to indicate a central position in the trig-loop when beam is horizontal.

In order to prevent magnetization, which impairs the vibratory action of the beam, trig-loop should be of brass or other non-magnetic material.

(k) The beam should be supported directly by a one-piece beam stand securely attached to a metal shelf supported by metal columns. Means should be provided for adjustment to maintain vertical alinement of steelyard-rod. The columns and shelf should preferably be of cast-iron.

Beam-rod and steelyard-rod should be provided with pin-and-clevice connections instead of hook connections. The steelyard-rod should be adjustable as to length by turnbuckles secured by lock nuts at both ends. The lock nuts should be additionally secured by binding screws.

(l) Multiplication at butt of beam should not exceed 800 to 1. In order to secure uniformity the following multiplications for levers of four-section scales of the straight lever type are suggested:

Main levers	4
Extension levers	10
Transverse extension lever	5
Shelf lever	4

(m) Recording beams should be used where spot weighing is performed.

(n) The sensibility reciprocal is the weight required to move the beam a definite amount from pointer or other indicating device of a scale. In scales provided with a beam and trig-loop the sensibility reciprocal is the added weight required to be placed upon the platform to break and turn the beam from a horizontal position of equilibrium in the middle of the trig-loop to a position of equilibrium at the top of the trig-loop. This may be determined by subtracting the weight instead of adding it, or by using the sliding poise on the beam, if this is done without jarring the beam.

For railroad track scales the angular movement or play should be 2 per cent. of the distance between the trig-loop and the fulcrum knife-edge, and the sensibility should correspond to 50 per cent. of the angular movement of the beam.

The sensibility reciprocal of a track scale should never be more than 100 pounds, and when the scale is new, should be not more than 50 pounds. For verification purposes, when new, a scale should be capable of adjustment to within 1/2000 (one-half pound to the thousand pounds) of the capacity.

Track scales should be kept in the closest possible adjustment, and a scale should be considered inaccurate when it cannot be adjusted, and such adjustment maintained to within two (2) pounds to one thousand (1,000) pounds, in excess or deficiency, when distributed test is made with two or more test loads. When only concentrated sectional tests are made, the maximum error for any position of the test load should not exceed three (3) pounds to each one thousand (1,000) pounds of test load used.

(o) Knife-edges, pivots and bearing-steels should be properly fitted, and so mounted, reinforced and designed in relation to flexure that uniform contact and pressure will be secured under all conditions of loading. The angle formed at contact faces of knife-edges and pivots should be symmetrical on a vertical line through the center of the section. Bearings should be self-aligning wherever practicable. Knife-edges should be fitted in machined ways. Pivots and bearing-steels should be so fitted, when necessary to comply with the requirements of this paragraph.

(p) Anti-friction contacts should be used where necessary to limit longitudinal displacement between knife-edges or pivots and bearings, and the angle formed at contact faces of knife-edges and pivots should be symmetrical on a vertical line through the center of the section. They should be smooth, at least as hard as the parts with which they come in contact, and so designed as to provide contact at a point on the line of the pivot edge.

To reduce friction between loops and levers, the friction faces of all loops should be flat, instead of cone-shaped, and the lever equipped with one-point contacts in line with the pivot edge (see cut under Rule 3 (d)).

3. Capacity.

(a) The capacity of a scale should be determined by the weight of the heaviest car to be weighed upon it, and for purposes of design a scale should support a train of such cars passing over it, plus the dead load, without stresses being developed in the members of the scale which are in excess of those specified in Section (b).

In order to secure a measure of uniformity and avoid a multiplicity of designs, due to different assumptions of loading and because of low impact, the following load factors, based on cars in train or coupled together, may be used for four-section scales from fifty (50) to sixty-five (65) feet in length:

Main lever	25 per cent.
End extension lever	50 per cent.
Intermediate extension lever	100 per cent.
Transverse extension lever	200 per cent.
Shelf lever	200 per cent.
Poise beam	175 per cent.

NOTE:—The load factor is the percentage of the capacity of the scale, which when modified by the multiplication factor, gives the load applied to the respective scale members. Manifestly, therefore, the load factors specified above are theoretically correct under the definition of "Capacity" for only one type of car and one length of scale.

(b) Working unit stresses per square inch are as follows:

Nature of Stress	Gray Iron Castings, Pounds	Steel Castings, Pounds	Wrought Iron, Pounds	Structural Steel, Pounds	Steel for Knife Edges and Bearings, Pounds
Tension	1,500	8,000	8,000	10,000	24,000
Compression	8,000	10,000	8,000	10,000	24,000
Transverse Bending—					
Tension	2,500	8,000	8,000	10,000	24,000
Compression	8,000	10,000	8,000	10,000	24,000
Shear	2,500	6,000	5,000	7,000	......
Torsion	2,500	6,000	......	7,000	......

Bearing stress per square inch on steel pins..........15,000 lbs.

Unit stress per square inch in cross-bending on steel pins, 15,000 lbs., assuming the center of bearing of strained members as the point of application of load.

NOTE:—It may be permissible to modify the assumption, as above, where the unit bearing pressure is less than that specified, or where the pins have a driving fit. In these cases the moment arm may be reduced by assuming the points of application of the load a sufficient distance from the face of the member to make the bearing stresses equal to 15,000 lbs. per square inch.

Bearing per linear inch of knife edge not to exceed....7000 lbs.

Bearing on concrete, per square inch.................. 400 lbs.

Maximum deflection at any point of lever, resulting from the load applied at the intermediate pivot with lever supported at end pivots as a simple beam and measured from a straight line joining the end pivots should not exceed .06 of an inch.

(c) In the design of loops and links the unit stresses should not exceed those specified in Section (b) and considering the end of the link as a simple beam, its section at the point of maximum bending moment should be determined by the formula $\frac{W}{4}(L - \frac{1}{2})$, wherein "W" equals the maximum load to apply to the link or loop, "L" equals the distance between the center lines of the depending sides and "1" equals the distance over which load is distributed.

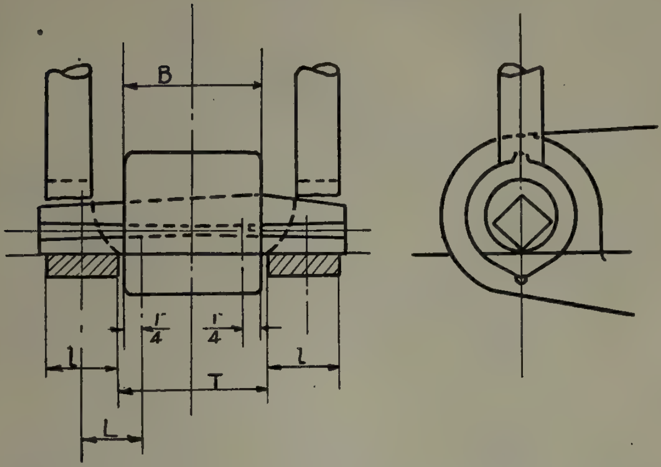
(d) Where practicable, knife-edges and pivots should be supported their full length by integral parts of the levers. The supports should be of such design as to carry the total load applied to the knife-edges or pivots without exceeding unit stresses in Section (b).

Where impracticable to so support the pivots, the bending moments should be determined as follows:

Let W = Total load on both ends of pivot.
L = Lever arm required.
1 = Bearing surface in loop.
T = Distance between friction faces of loop.
B = Width of boss or sustaining member enveloping pivot.
M = Bending moment in pivot.

$$\text{Then } L = \frac{1}{2} + T - B + \tfrac{1}{4} \text{ in.}$$

$$\text{And } M = \frac{WL}{2} = \frac{W}{2} \left(\frac{1}{2} + T - B + \tfrac{1}{4} \text{ in.}\right.$$



High carbon steel may be used for knife-edges, pivots and bearings, but for enduring wear under heavy weighing service, special alloy steel possessing the following physical properties, with the internal strains relieved by drawing after hardening, is recommended:

Ultimate tensile strength	200,000 lbs. per sq. in.
Elastic limit	165,000 lbs. per sq. in.
Elongation in 2 in.	5 per cent.
Reduction in area	25 per cent.
Unit stress in transverse bending	24,000 lbs. per sq. in.

(e) Structural steel used for weigh-bridge girders and for the cross-girders supporting the dead rail should conform to the specifications for steel structures as adopted by the American Railway Engineering Association, except as provided in Section (b). In order to avoid distortion, each pair of weigh-bridge girders should be fabricated complete with sway and lateral bracing in the shop under proper inspection; where this method is impracticable and field assembly is necessary, each pair of girders should be placed in proper alinement and the bracing then introduced and secured by bolts or rivets.

In Table No. 1, the recommended sections for weigh-bridge girders for differing lengths and capacities of four-section scales are tabulated. In Table No. 2, recommended sections for transverse floor beams for varying axle loads are tabulated.

TABLE 1—WEIGHBRIDGE GIRDERS

Length of Scale C. to C. of end Sections,	Span C. to C. of Sections,	Main Lever Capacity,	Dead Load Main Lever Reaction,	Live Load Main Lever Reaction,	Scale Capacity (Load Factor 0.25),	Bureau of Standards Representative Car			Dead Load moment one girder	Required Section Modulus (f=10000)	Alternative Girder Sections					
						Wheel Load,	Car Load,	Live Load moment one girder			Bethlehem Girder Beams		Double I Beams		Single I Beams	
											Sizes	Sec. Mod.	Sizes	Sec. Mod.	Sizes	Sec. Mod.
feet	feet	pounds	pounds	pounds	tons	pounds	tons	inch lbs. ÷ 1000	inch lbs. ÷ 1000							
60 TON SECTION																
45	15	60,000	3,750	56,250	112.5	23,440	93.76	1,476.7	84.4	156.1	18"x92#	176.8	....	......	1-24"x80#	173.9
48	16	60,000	4,000	56,000	112.0	22,400	89.60	1,612.8	96.0	170.9	18"x92#	176.8	....	......	1-24"x80#	173.9
51	17	60,000	4,250	55,750	111.5	21,540	86.16	1,744.7	108.4	185.3	18"x92#	176.8	....	......	1-24"x100#	198.3
54	18	60,000	4,500	55,500	111.0	20,810	83.24	1,872.9	121.5	199.4	20"x112#	234.2	....	......	1-24"x100#	198.3
57	19	60,000	4,750	55,250	110.5	20,190	80.76	1,998.8	135.4	213.4	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
60	20	60,000	5,000	55,000	110.0	19,640	78.56	2,121.1	150.0	227.1	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
63	21	60,000	5,250	54,750	109.5	19,160	76.64	2,241.7	165.4	240.7	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
66	22	60,000	5,500	54,500	109.0	18,730	74.92	2,360.0	181.5	254.2	24"x120#	300.6	2-24"x80#	347.8	....	......
69	23	60,000	5,750	54,250	108.5	18,350	73.40	2,523.1	198.4	272.2	24"x120#	300.6	2-24"x80#	347.8	....	......
72	24	60,000	6,000	54,000	108.0	18,000	72.00	2,687.4	216.0	290.3	24"x120#	300.6	2-24"x80#	347.8	....	......

75 TON SECTION																
45	15	75,000	3,750	71,250	142.5	29,690	118.76	1,870.5	84.4	195.5	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
48	16	75,000	4,000	71,000	142.0	28,400	113.60	2,044.8	96.0	214.1	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
51	17	75,000	4,250	70,750	141.5	27,340	109.36	2,214.5	108.4	232.3	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
54	18	75,000	4,500	70,500	141.0	26,440	105.76	2,379.6	121.5	250.1	24"x120#	300.6	2-24"x80#	347.8	....	......
57	19	75,000	4,750	70,250	140.5	25,670	102.68	2,541.3	135.4	267.7	24"x120#	300.6	2-24"x80#	347.8	....	......
60	20	75,000	5,000	70,000	140.0	25,000	100.00	2,700.0	150.0	285.0	24"x120#	300.6	2-24"x80#	347.8	....	......
63	21	75,000	5,250	69,750	139.5	24,410	97.64	2,856.0	165.4	302.1	24"x120#	300.6	2-24"x80#	347.8	....	......
66	22	75,000	5,500	69,500	139.0	23,890	95.56	3,010.1	181.5	319.2	24"x140#	350.1	2-24"x80#	347.8	....	......
69	23	75,000	5,750	69,250	138.5	23,420	93.68	3,220.3	198.4	341.9	24"x140#	350.1	2-24"x80#	347.8	....	......
72	24	75,000	6,000	69,000	138.0	23,000	92.00	3,433.9	216.0	365.0	24"x140#	350.1	2-24"x80#	347.8	....	......
100 TON SECTION																
45	15	100,000	3,750	96,250	192.5	40,100	160.40	2,526.3	84.4	261.1	24"x120#	300.6	2-24"x80#	347.8	....	......
48	16	100,000	4,000	96,000	192.0	38,400	153.60	2,764.8	96.0	286.1	24"x120#	300.6	2-24"x80#	347.8	....	......
51	17	100,000	4,250	95,750	191.5	36,990	147.96	2,996.2	108.4	310.5	24"x120#	300.6	2-24"x80#	347.8	....	......
54	18	100,000	4,500	95,500	191.0	35,810	143.24	3,222.9	121.5	334.4	24"x140#	350.1	2-24"x80#	347.8	....	......
57	19	100,000	4,750	95,250	190.5	34,800	139.20	3,445.2	135.4	358.1	26"x150#	396.5	2-24"x100#	396.6	....	......
60	20	100,000	5,000	95,000	190.0	33,930	135.72	3,664.4	150.0	381.4	26"x150#	396.5	2-24"x100#	396.6	....	......
63	21	100,000	5,250	94,750	189.5	33,160	132.64	3,879.7	165.4	404.5	26"x150#	396.5	2-24"x100#	396.6	....	......
66	22	100,000	5,500	94,500	189.0	32,480	129.92	4,092.5	181.5	427.4	28"x165#	468.8	2-24"x105#	468.6	....	......
69	23	100,000	5,750	94,250	188.5	31,880	127.52	4,383.5	198.4	458.2	28"x165#	468.8	2-24"x105#	468.6	....	......
72	24	100,000	6,000	94,000	188.0	31,330	125.32	4,677.6	216.0	489.4	28"x165#	468.8	2-24"x105#	468.6	....	......

Beams in pairs to be spaced 12" C. to C.

TABLE 2—TRANSVERSE FLOORBEAMS

Span 10′ clear, 11′ C. to C. bearings, Dead rail offset 16″
Floorbeams 2′ 6″ C. to C.
75 per cent of axle load carried by one beam

Axle Loads	Live Load Moment, Inch Lbs. ÷ 1,000	Required Section Modulus (f=10,000)	Alternative Floorbeam Sections			
			Bethlehem Beams		I Beams	
			Sizes	Sec. Mod.	Sizes	Sec. Mod.
50,000	984.8	73.9	1-15″x54#	81.3	1-15″x60#	81.2
55,000	1083.3	81.3	1-15″x54#	81.3	1-15″x60#	81.2
60,000	1181.8	88.6	1-15″x73# Girder	117.8	2-15″x42#	117.8
65,000	1280.3	96.0	1-15″x73# Girder	117.8	2-15″x42#	11.88
70,000	1378.8	103.4	1-15″x73# Girder	117.8	2-15″x42#	11778
75,000	1477.3	110.8	1-15″x73# Girder	117.8	2-15″x42#	117..

Beams in pairs to be spaced 12″ C. to C.

(f) Bids for scales should be accompanied by detailed specifications and by plans showing general arrangements. After order is placed, the manufacturer will also, when requested, furnish stress sheets and plans showing dimensions of levers and of the various parts of the scale sufficiently in detail for making a satisfactory check.

4. Length.

(a) The length of scales should be considered as the distance between ends of scale rail.

(b) The ends of scale rail should not project beyond knife-edges of the end main levers.

(c) When cars are to be weighed spotted, the scale rail should be of sufficient length to permit the entire car to be placed on the scale, and preferably longer, to facilitate spotting. A length of not less than fifty (50) feet is recommended.

(d) When cars are to be weighed in motion, the speed should not exceed four (4) miles per hour and each car should be entirely and alone on the scale a minimum time of three (3) seconds. The length of scale should be such that these conditions will obtain for cars normally weighed. When scales are of such design or length as not to permit the above speed, cars should be passed over the scale at a lower speed or be spotted if necessary to secure accurate weights.

5. Location.

The proper location of scales depends principally on the following conditions:

(a) The volume of traffic to be weighed in comparison with that switched over the scales and not to be weighed.

(b) Whether scale is to be equipped with dead rail or relieving gear.

(c) Whether run-around track will be installed for switching with separate track for weighing.

(d) Whether cars are to be weighed spotted or in motion.

(e) The cost of extra switching, when scales are not located on lead to classification track.

(f) Cost of maintenance when scale is located on lead to classification track and only a small proportion of cars are to be weighed.

(g) The necessity for quick despatch of cars that are weighed.

Note:—So much depends on local conditions affecting the different carriers that it would be difficult to give exact rules in connection with the above suggestions. It is recommended, however, that there be not less than 50 feet of tangent track at each end of scale rails. When only a small proportion of cars handled are to be weighed, the rails leaving the scale in the direction of weighing may be curved and the dead rail straight, or the curvature may be equalized between them.

6. Grade.

(a) When scales are located on lead to classification tracks in hump yards they shall be at sufficient elevation that cars will run by gravity as far as desired into classification yard, considering a maximum speed of four miles per hour over the scales.

(b) The distance and grade from apex of hump to scale should be such that the speed of free-running cars with varying lengths of wheel base will be automatically controlled without brake application, so that a speed of four (4) miles per hour will not be exceeded while passing over the scale, and cars should be so spaced that the weighing period of three (3) seconds will not be reduced.

(c) Scales to be used for motion weighing should be constructed with the scale rails on a gradient not greater than one per cent. The weighing mechanism must in all cases be installed on a level plane, with supports introduced to fix the weighing rails on the desired gradient.

(d) Where it is the practice for one car rider to take several cars together into the classification track, the same grade as on the scale should be maintained for at least 100 and preferably 200 feet beyond the scale in the direction of weighing, so that cars may be stopped easily by car rider and that succeeding cars will not cause excessive impact when striking the car ahead, which should occur not less than one car length from scale.

(e) When scales are installed not in connection with humps, they should be at sufficient elevation for protection against surface water. In order to prevent impact on scales and facilitate weighing, it is also necessary that there be sufficient elevation to permit cars to run away from scale by gravity after being weighed.

7. Pit and Foundation.

(a) The scale pit should be constructed of Portland cement concrete or of cut stone masonry laid with Portland cement mortar. It should be designed and constructed with especial care to prevent settlement.

(b) The bearing areas of the footings of the different parts of the pit on the foundation should be such that the bearing pressure per square foot on the soil will be uniform throughout and not exceed:

For fine sand or clay	4,000 lbs. per sq. ft.
For coarse sand and gravel or hard clay	6,000 lbs. per sq. ft.
For large boulders or solid rock	20,000 lbs. per sq. ft.

If the soil has not a safe bearing capacity equal to that of fine sand or clay, its bearing capacity should be increased; by drainage, by adding a layer of gravel or broken stone, or by driving piles.

(c) Concrete should be composed of one part of Portland cement to not more than three parts of sand and not more than six parts of pebbles or crushed stone. The qualities of the materials and the methods of mixing and placing the concrete should be in accordance with the railroad company's specifications for first-class concrete.

(d) The tops of piers and of parts supporting stands or other metal parts should be above the floor of the pit a distance sufficient to prevent the accumulation of water under the bearings. The tops of piers and walls supporting parts of the scale or superstructure should be finished level and at the correct elevation without the use of shims or grouting. The finishing of the scale stand bearings to exact level and elevation is especially important. The floor of the pit should slope uniformly to the drainage outlet and should not be less than six inches thick.

(e) Where necessary to prevent seepage of water through foundations into the scale pit, they should be waterproofed and drained into a waterproofed cistern located outside of scale pit and equipped with either hand pump, air siphon or steam siphon.

(f) Drainage should be provided in all cases where there is a possibility of water getting into the pit and where excessive seepage is not present and there is sufficient fall, pipe drainage should be used.

(g) A minimum period of 10 days should elapse between the placing of last concrete and the putting of the scale in service to permit proper setting of concrete. The proper setting will be influenced by the prevailing temperature and weather conditions during that period, and this should be given due consideration.

(h) The masonry should extend at least fifteen (15) feet, and preferably twenty-five (25) feet, from the pit face of the end wall at the approach and back under the track, to preserve line and surface of approach tracks, which is difficult when ballast is used.

The longer approach walls are desirable on account of ballast beyond them giving way, thereby making it difficult to keep the approach rail properly anchored at the scale end.

(i) The foundation pit should be of ample size to allow freedom in making inspection and repairs, and access to it should be from the side if practicable; otherwise, by means of stairway or fixed ladder from scale-house.

The length of pit inside of end walls should be not less than two (2) feet greater than the length of the scale parts.

8. Installation.

(a) Scales should be installed with dead rail or relieving apparatus.

(b) The deck or platform should be of the fixed type, so that the balance of the beam will be least affected by weather conditions, etc. It should be made as nearly dirt- and waterproof as possible.

(c) Scales to be used for spot-weighing should be constructed with scale rails level, and, where cars are weighed coupled together at one end, rails approaching in the direction of weighing should be in the same plane with scale rails for a distance of at least fifty (50) feet.

(d) Wedge or other means of adjustment used between bridge and scale supports to assure proper distribution of loading should be set as low as possible when scales are installed, as future lining usually requires raising bridge rather than lowering it.

(e) Scale should be set directly on foundations or on metal bedplates resting on foundations. The surfaces of castings which bear on masonry, on steel members, or on each other should be machined.

(f) Scale parts, where necessary, should be securely anchored to foundations, and it is desirable that means of slight adjustment, longitudinally and transversely, be provided for properly setting scale, interchanging scales in the same pit, etc., in order to secure perfect freedom of action for all parts in suspension.

(g) Supports for scale beam and shelf lever should rest directly on scale foundation, and suitable clearance should be provided between the inside of the scale office and the beam supports and shelf. (See Rule 2 (k)).

(h) The use of extension levers between transverse extension lever and scale beam is undesirable, except when shelf lever is used for an extension.

(i) To prevent interference, proper clearance between the movable parts and the adjacent fixed parts should be provided and maintained.

(j) One-piece scale rails are desirable, and they should be of adequate section for supporting the load.

(k) An efficient transfer rail, or other connection, may be used to prevent impact of cars moving over joint between approach and scale rails, such contrivance to be so designed and maintained as not to interfere with the action of the scale.

(l) Approach and scale rails should be anchored to prevent creeping and should be maintained in proper line and surface.

Where anti-creepers will not prevent creeping of rails, switch points should be used.

(m) Scale pits should be heated wherever practicable and necessary to prevent freezing and to keep pit dry, thereby preventing rust

(n) Proper ventilation will be of assistance in keeping the levers of the scale and the scale pit dry. However, it may not be advantageous under conditions where the outside air entering the pit contains more moisture than the air in the pit, or is warm and cooled below the dew point when it enters the relatively cooler pit, thereby causing condensation or cold sweating of the scale parts. The method of ventilation, therefore, should be such that these conditions may be controlled, as far as practicable.

(o) Scale pits should be properly lighted for purposes of cleaning, inspection and testing.

(p) Scale houses should be constructed at track scales for proper housing and protection of scale beam and protection of weighmaster.

(q) The interior and exterior of scale houses should be amply and properly lighted to afford proper facilities for weighing and the prevention of mistakes in reading scale beam, car numbers and stenciled light weights. This applies more especially where cars are weighed at night.

9. Maintenance and Operation.

(a) All track scales should be numbered and referred to by number and location.

(b) Extensive repairs to scales, such as renewal of or sharpening of pivots, should be made in properly appointed shop.

(c) When scales are in service regularly, scale parts, substructure and foundations should be cleaned at least twice a month, and when exposed to the elements, or otherwise so located that they are liable to become clogged with ice or dirt, should be cleaned oftener, if necessary.

(d) The application of rust preventives to bearings is desirable, but they should be so applied as not to interfere with the proper working of scale.

(e) If ice obstructs the levers, salt should not be used to melt it; artificial heat should be used wherever practicable.

(f) Equipment should not be allowed to stand on the scales, except when being weighed.

(g) Engines or other equipment not to be weighed should not be passed over the scale rail, except on authority of the department having supervision over the installation and maintenance of scales.

(h) Cars should not be bumped off scales by engine or another car on the dead rail, nor be pulled across the scale coupled to another car moving over the dead rail.

(i) Enginemen should not apply sand to scale or dead rail, nor should the injector on engine be applied when engine is standing on or passing over scale.

The slipping of engine drivers on either scale or dead rail is injurious to the structure and should be avoided whenever possible.

(j) The weighing beam should be balanced before the scale is used and when not in use should be locked with beam catch.

(k) Cars should not be violently stopped on scale by impact, by the sudden application of brakes or by throwing obstructions under the wheels. When pushing cars off scale which have been stopped for weighing or otherwise, impact must not occur at a speed greater than two miles per hour. When necessary for any reason to run cars over scale rails, the speed must not exceed four (4) miles per hour.

(l) The weighmaster should familiarize himself with construction of scale and make such inspections at such intervals as are necessary to determine if scale is in proper working condition.

(m) Persons appointed to inspect and clean scales should be properly instructed, and it is desirable that they be present with the scale inspector when scales are tested.

(n) Scales and structural steel should be cleaned and painted with one coat of red lead paint before installation, one coat after installation, and at such other times as may be necessary.

10. Testing.

(a) The standards of mass for testing scales should be derived from primary weights, verified by the U. S. Bureau of Standards, Washington, D. C., to within what is known as their "Class B Tolerance." Such weights can be obtained either direct or through scale manufacturers. The 50-pound secondary or working cast-iron weights, which are transported from place to place and used directly in testing scales, should be rectangular, and of such design as to facilitate stacking; they should be free from pockets, blowholes, etc., which are liable to catch and hold foreign matter. No adjusting cavity or cavities in the bottom of the weights should be permitted.

These weights should be properly painted, surfaces maintained in good condition, and be tested and adjusted in comparison with master-weight which has been verified to within "Class C Tolerance" (U. S. Bureau of Standards). The working weights shall be adjusted to within 25 grains and maintained to within 100 grains of their true values.

Note:—The standards for testing scales in the Republic of Mexico must be in accordance with the metric system standards and will be verified by a Federal scale inspector in accordance with the Federal laws.

(b) Track scales in regular car weighing service should be tested at least every three months with test car or test weights weighing not less than thirty thousand (30,000) pounds.

(c) Scales when installed, and periodically thereafter, should be given a graduated test with two or more test loads up to the weight of the heaviest cars normally weighed. The necessity for the frequency of such a test depends on the design, capacity and method of installation of the scale used, the wear of scale pivots, and the amount of weighing performed.

(d) Where frequent tests cannot be made in accordance with paragraph (c) a test should be made each week by weighing a heavily loaded freight car with as short a wheel base as is obtainable, on each end and center of scales. When scale is equipped with automatic weighing attachment the car should, in addition to the above, be weighed spotted on trip end of scale and in motion with automatic attachment connected. A report of these tests should be sent to officer in charge of scales and weighing.

(e) In addition to the above, a daily test should also be made on each scale equipped with automatic attachment, by weighing a car spotted on trip end of scale with beam, also in motion with automatic attachment connected. A book record of this and other tests is to be kept by weighmaster.

11. Automatic Weighing and Recording Devices.

Efficient automatic weighing and recording devices may be used where desired. There has been in the past, however, and may be at present, an impression by some that the automatic weigher and recorder will overcome all outside influence and give correct results regardless of scale and track conditions and speed at which cars are handled over the scale. This is an erroneous impression, as it is absolutely necessary that the scale and the automatic device, as well, be in first-class condition, with properly maintained approach tracks, and cars must be run at a slow rate of speed, with particular attention to steadiness of motion if best results are to be obtained.

In addition to the above track scale specifications and rules, your Committee offers as information the following rules and specifications covering equipment for testing track scales, which were prepared by the Sub-Committee on Standards of the American Railway Association and which have been adopted by that association. Your Committee has not yet made any study on equipment for testing track scales and is therefore not prepared at this time to recommend the adoption of the following rules, nor the printing of them in the Manual:

EQUIPMENT FOR TESTING.

It is desirable for verifying or sealing test weights and test cars to have, in addition to standards of mass prescribed above:

(a) An accurate even arm balance of 100 lbs. capacity in each pan, sensitive when loaded to two grains.

(b) A master scale of sufficient length and capacity for sealing test-weight cars should be installed under cover, at a location as free from vibrations, resulting from machinery, train or other causes, as possible. The use of it should be limited to the verification of test cars or for other special weighing, where extreme accuracy is required. It should not be used for general weighing purposes, nor be run over with cars or material not to be weighed. A scale of the two-section track scale type is recommended.

(c) The length of weighing rail should be sufficient to weigh in one operation test cars in use or contemplated. Scale with weighing rail not less than ten (10) feet in length is recommended. The approach rails to master scale should be on a tangent for a distance slightly in excess of the longest wheel base cars to be weighed on the scale. To facilitate test with equipment such as is used by the Bureau of Standards, the tangent on at least one approach should not be less than fifty (50) feet.

(d) The capacity of scale should be determined by the heaviest load to be weighed upon it when concentrated on a five-(5)-foot wheel base without stresses being developed in the parts of scale in excess of those specified in Section 3 (b), (c) and (d). A scale of not less than one hundred thousand (100,000) pounds is recommended.

(e) Scale should be equipped with single beam with capacity not to exceed one thousand (1,000) pounds, the value of minimum graduations not to exceed five (5) pounds. Multiplication at butt of beam 100 to 1, multiplication of the beam 10 to 1, and ratio of counterweights 1,000 to 1 are recommended.

(f) The angular movement of the beam should be limited by the trig-loop, and should be two (2) per cent. of the distance between the trig-loop and the fulcrum knife-edge. The sensibility reciprocal should correspond to fifty (50) per cent. of the angular movement of the beam.

The sensibility reciprocal should never be greater than ten pounds, and for a new scale should not be greater than five (5) pounds.

(g) Master scale, when installed, and at least once each year thereafter, should be given a graduated test up to the weight of the heaviest loads to be weighed upon it (preferably to full capacity).

Scale should be capable of adjustment and maintenance to within a tolerance on leverage ratio of one (1) part in ten thousand (10,000).

Tolerance on counter-poise weights is as follows:

Weight Lbs.	Tolerance Grains.	Weight Lbs.	Tolerance Grains.
50	10	2	1.5
25	6	1	1.0
20	6	0.8	1.0
15	4	0.5	0.5
10	4	0.4	0.5
8	3	0.3	0.5
5	3	0.2	0.5
4	2	0.1	0.3
3	2		

(h) To facilitate calibration of master scales, the use of special weights heavier than the usual fifty-(50)-pound commercial test weights are desirable.

Tolerance of weights weighing respectively 2,500, 5,000 and 10,000 lbs. is as follows:

Weight	Tolerance	
Lbs.	Grains.	Lbs.
2,500	440	.063
5,000	650	.093
10,000	975	.139

(i) Master scales should be kept clean, dry and free from rust, and it is recommended that this work be looked after only by an experienced scale man.

NOTE:—Rules 2 of above specifications for track scales (b), (c), (f), (g), (h), (i), (j, except first paragraph), (k), (n, first paragraph), (o) and (p); Rule 3 (b), (c), (d), (e) and (f); Rule 4 (a) and (b); Rule 7 (a), (b), (c), (d), (e), (f) and (h); Rule 8 (b), (d), (e), (f), (g), (h), (i), (j), (k), (l), (m), (n), (o) and (p); Rule 9 (b), (d), (f), (j), (k) and (n) apply also to master scales as well as track scales, but it should not be overlooked that extraordinary care is necessary in the design and installation of master scales, and preparation of foundations to insure stability, in order that scales will meet the sensibility and tolerance requirements specified above and consistently hold their adjustment as determined by repeated weighings.

Scale Test Cars.

(a) For general track-scale testing, test cars should weigh not less than a total of thirty thousand (30,000) lbs., nor more than eighty thousand (80,000) lbs. For making graduated tests and to simplify computations, cars weighing eighty thousand (80,000) lbs. and forty thousand (40,000) lbs., respectively, are suggested. The maximum weight of 80,000 lbs. is suggested principally in order to reduce the number of restricted movements due to weight limits on scales, bridges, etc.

(b) Scale test cars of proper design should have the following characteristics:

1. All-metal construction.
2. Length of wheel base not to exceed 7 ft.
3. Load distributed uniformly on wheels.
4. No unnecessary ledges or projections likely to catch and hold dirt.
5. No unnecessary parts.
6. Strength and durability, so that frequent repairs will not be necessary.
7. Surface area reduced as much as possible, to limit wind pressure.
8. Accessibility of all parts for inspection.

9. Roller or ball bearings reduce rolling resistance, thereby providing for ease of movement by scale inspector. They do not require sponging and repacking of journal boxes, which materially changes weight of test car between periods of verification, and for these reasons are preferable to journal bearings.

(c) Test cars may be designed with body of solid castings, with space provided for test weights or other material to increase the sealed or verified weight a comparatively small amount, or with body of plate steel with space for test weights or other material weighing as much as the car. It is thought that car of the former type will better meet the requirements under Section (b).

(d) When supercargo (consisting of tools, overclothes, etc.,) is carried in test car, it should be removed when the weight of car is being verified on master scale, also when testing track scales. To facilitate handling of supercargo, it should be contained in a removable steel box, properly stenciled to show that it is not a part of the test load. There should be stenciled on the outside of each of the doors of the compartment in which this box is carried the following note:

"This box contains supercargo, such as tools, etc., used for adjusting track scales, and must be taken out of car when car is weighed on master scale and when testing track scales."

(e) Scale test cars should be moved on the rear end of trains, just ahead of the caboose.

(f) Scale test cars should not be kept on trains in yards while the latter are being switched, but should be so placed that rough handling will be avoided. In no case should these cars be subjected to impact at a speed greater than two (2) miles per hour.

(g) All excess weight, resulting from the accumulations of snow and ice, should be removed from scale test cars before they are placed on scales for the purpose of testing. To remove this, an engine with steam-hose connections may be used to thaw it, or hydro-carbon, where available, may be employed if used with care.

(h) Oiling and repacking of test cars should be looked after while test car is at master scale for verification.

(i) Scale test cars should be verified on master scale at least every three (3) months, or after each general test trip.

(j) In order to maintain the verified weight of the scale test cars at all times, no repairs of any nature should be made while in transit, or boxes sponged, without notifying the scale inspector in charge of the car, in order that he may be present to determine and arrange to take care of any difference between the weight of parts applied and those removed. To insure compliance with this rule, there should be located in a conspicuous place, so that it can be read from either side of the car, a badge-plate with some such notice as: "Do not oil or repack boxes or make repairs to this car unless directed by scale inspector."

(k) In case a scale test car is damaged so as to require extensive or heavy repairs, it should be returned to the master scale for verification after the repairs have been completed.

CONCLUSIONS.

Your Committee recommends:

(1) That the Catechism of Yard Design be printed in the Manual of Recommended Practice.

(2) That the Track Scale Specifications and Rules be adopted and printed in the Manual.

(3) That the rules adopted by the American Railway Association on Equipment for Testing Track Scales and on the subject of Scale Test Cars be received as information and printed in the Proceedings.

SUGGESTIONS FOR NEXT YEAR'S WORK.

(1) Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.

(2) Report on handling of freight in double-deck freight houses and cost of operation. Also report on handling of freight by mechanical means.

(3) Continue study of typical situation plans of passenger stations and methods of their operation.

(4) Report on classification yards.

Respectfully submitted,

The Committee on Yards and Terminals.

Appendix A.

TRACK SCALE LOAD FACTORS.

DISCUSSION OF THE REPORT OF COMMITTEE XIV—YARDS AND TERMINALS.

By O. E. Selby,

Principal Assistant Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway.

The adoption of the constant live load factor for inner section main levers (0.25) and the dependent factors for extension levers contained in Article 3 (a) of the specifications submitted by the Committee seems to the writer not to be justified.

The live load factor (which is a term originated by the Bureau of Standards) depends on only two things: the distance between centers of scale sections, and the axle spacing of the car load considered. Any particular factor can be correct for only one combination of scale length and axle spacing. It happens that the one recommended is not correct for the usual scale lengths or the axle spacing of typical cars. The adoption of one load factor for scales of all lengths within the limits given would nullify, or rather render fictitious, the definition of capacity given in Article 3 (a). This definition is strictly correct when the correct load factors are used, and gives the real usable car load capacity of the scale for such cars as are in common use. The use of the factor 0.25 would amount to the fixing of the definition of capacity as twice the section capacity, and such a definition would give little clew to the real car load capacity. A glance at columns 6 and 8 of Table No. 1 in the Committee's report will show the comparison between the fictitious capacity fixed by the 0.25 factor and the real capacity in terms of the U. S. Bureau of Standards representative car.

The writer is familiar with the course of the discussions between this Committee and the corresponding committee of the American Railway Association which resulted in the recommendation of this load factor (and the dependent factors for extension levers) with the explanatory note. The arguments in its favor which are discussed herein may therefore be considered to be those presented by the American Railway Association committee.

The principal arguments advanced in favor of the 0.25 factor are:

(a) The load factors derived from two cars coupled do not represent a weighing condition and smaller factors obtain while cars are being weighed. The answer to this is that by the definition of capacity the use made of load factors is to determine the stresses existing in the parts under service conditions and to proportion the parts to resist those stresses. The fact of weighing or not weighing has nothing to do with the magnitude of the stresses or the safety of the structure. Accuracy of weighing depends on many things beside the stresses in the parts,

(b) Scales proportioned for the 0.25 factor have given satisfactory service. So have bridges given satisfactory service under loads greater than those for which they were proportioned. There necessarily is a margin between proportions which are just sufficient for acceptable results and those which are ample for all conditions. If the margin is too great it should be reduced by raising the unit stresses; not by proportioning for fictitious loads.

(c) The use of the correct load factor would increase the cost of scales unduly. This argument proceeds from motives of expediency and should not have any weight for that reason, even if it had any truth back of it. A little reflection will show that the cost of a scale of given size and proportions would not be increased or diminished one cent by any change in the method of figuring its capacity, and certainly self-deception as to the amount of scale capacity received for a certain number of dollars will not save any money.

(d) The use of the correct factors would rule out scales now in service and scales on the market which give results within the prescribed tolerances. The purpose of the specifications is to design new scales, not to pass upon the sufficiency of old ones. That will be taken care of by the Bureau of Standards by the methods so happily set forth in its circular on capacity rating. Even the conceded existence of scale installations which are not up to their alleged capacity should not be a bar to progress in the correct design and installation of scales any more than the existence of light bridges or insufficient clearances should bar the introduction of heavier bridges or liberal clearances. As to scales on the market, the argument may be dismissed with the statement that nothing would be changed about the scales or their price, but that the truth would have to be told about their capacity.

(e) It is desirable to have one load factor for scales of all lengths to simplify design and standardize manufacture. To answer this, it is sufficient to point to the action of the recently formed Scale Manufacturers' Association—than whom none could be more interested. This body proposes to simplify design and standardize manufacture by confining the marketing of scales to those of three standard section capacities regardless of length. The question of usable car load capacity will be left to the purchaser. This is analogous to the capacity rating of existing scales and indicates that in the future the purchase of scales is likely to be a matter of selection rather than design.

The writer advocates the use of the correct load factor for each length of scale based on the Bureau of Standards representative car for the following reasons:

(1) The correct factor is determined by an extremely simple formula.

The Bureau of Standards representative car has two four-wheel trucks spaced 22 feet between centers, truck axles 5½ feet between centers, and near axles of adjacent cars 6½ feet between centers. The greatest load on an inner section main lever occurs when one of the inner axles of the group of four under the ends of adjacent cars is over the section. For this position, the lever reaction, $R = 4W \frac{L-6}{L}$, in which W is the weight on one wheel and L is the distance center to center of sections, limited to values 12 to 22 ft. inclusive.

The load factor, $\frac{R}{8W} = \frac{L-6}{2L}$.

The evaluation of this factor for different values of L involves only one simple division. The values for span lengths from 16 to 22 ft. inclusive are given in column 3 of Table A.

(2) The resulting proportions will be correct and consistent throughout all parts.

The load factor is simply a device for figuring the stresses. It is in the nature of a formula; the use of an incorrect or even an approximate average factor would give incorrect or only approximately correct results.

If the 0.25 factor is used, a strict following of the definition of capacity would result in the proportioning of the weighbridge for a heavier car load than for the scale parts. This is true for all scales longer than 36 ft. between centers of end sections. Scales as short as 36 ft. are not to be considered.

(3) The Bureau of Standards representative car best typifies existing car loads and approximates probable developments in loading.

The typical heavy freight car on all roads has four-wheel trucks. They are used for capacities of from 100,000 to 150,000 lbs. They vary greatly in length, but for the reason that the criterion for maximum loading on the scale parts involves only the trucks of adjacent cars, the length of the car has no influence on the load factors of scales up to 66 ft. long. The spacing of the truck axles in different cars varies only a few inches. The trucks are placed close to the end no matter what the length of the car, and the resulting distance between axles of adjacent cars varies little from the distance 6½ ft. adopted.

Looking at future developments in loading, a 150,000 lbs. capacity car has an axle load of nearly 54,000 lbs. Probably the greatest allowable car axle load will be 60,000 lbs., requiring a 120 tons capacity scale. This will be attained in a car of 80 to 85 tons capacity. Greater car capacity must be obtained by the use of six-wheel trucks. Such cars are not new. The Norfolk & Western and Virginian Railways have coal cars for capacities of 90 and 120 tons respectively. The New York Central Railroad has 100 tons capacity flat cars and 110 tons capacity well cars.

TABLE A—COMPARISON OF LOAD FACTORS FOR DIFFERENT TYPES OF CARS ON FOUR SECTION SCALES.

1	2	3	4	5	6	7	8	9
Length of Scale C. to C. of End Sections	Span C. to C. of Sections	Load Factor, Inner Section Main Lever		Ratios of Load Factors Col. 3÷Col. 4	Weight of 6-wheel truck Car Giving Same Scale Stresses as a 120 Ton 4-wheel Truck Car	Per cent. Over-load from a 180 Ton Six-wheel Truck Car (60,000 lbs. Axle Load) on a Scale Designed for a 4-wheel Truck Car, 60,000 lbs. Axle Load Using:		
		U. S. Bureau of Standards Representative Car, 4-wheel Trucks	Norfolk and Western Type Coal Car, 6-wheel Trucks			Load Factors in Column 3	Load Factor 0.25 Constant	Load Factor 0.30 Constant
3 L	L	$\frac{L-6}{2L}$	$\frac{L-8}{2L}$	$\frac{L-6}{L-8}$	Tons			
48	16	.313	.250	1.25	150.0	33	50	25
51	17	.324	.265	1.22	146.7	36	59	33
54	18	.333	.278	1.20	144.0	39	68	40
57	19	.342	.290	1.18	141.8	41	74	45
60	20	.350	.300	1.17	140.0	43	80	50
63	21	.357	.310	1.15	138.5	44	86	55
66	22	.364	.318	1.14	137.2	46	91	59

From the characteristics of these six-wheel truck cars, we may infer the direction of future development. In the Norfolk & Western and Virginian cars, the truck axle spacing is 4 ft. 6 in. and the spacing of axles of adjacent cars is 7 ft. 6 in. or less. Using the safe and simple figure 7 ft., the inner section main lever reaction, $R = 6W \frac{L-8}{L}$.

The load factor, $\frac{R}{12W} = \frac{L-8}{2L}$,

in which L must not be smaller than 16 ft.

In the well cars, the corresponding spacings are 5 ft. 4½ in. and (average of 5 and 5½ ft.) 5 ft. 3 in. It happens that these dimensions give the same reaction and load factor as the coal cars described above. These load factors are given in column 4 of Table A. They are smaller than for the car with four-wheel trucks, which means that for a given total weight of car and contents, the six-wheel truck car would produce smaller stresses in a track scale than the four-wheel truck car. In column 5 of Table A are given the ratios of the load factors for 4-wheel and 6-wheel truck cars. These ratios reveal that, for example, a scale of 54 feet between centers of end sections, designed for the 4-wheel truck car would carry a 6-wheel truck car of 20 per cent. greater total weight with the same stresses. For the usual scale lengths of from, say, 48 to 63 ft. between centers of end sections, the ratios in column 5 range from 1.25 to 1.15 with 1.20 as an average.

The ratio of weights of existing cars of the two types is about the same as the foregoing average, as is shown by the following comparison:

N. & W. 6-wheel truck car—		4-wheel truck car—	
Capacity load	180,000	Capacity load	150,000
10 per cent. over load.....	18,000	10 per cent. over load.....	15,000
Weight of car, say.........	60,000	Weight of car, say.........	50,000
Total weight	258,000	Total weight	215,000

The ratio 258,000 ÷ 215,000 is exactly 1.20, indicating that if future increase in both types is proportionate, the Bureau of Standards representative car approximates future loading for usual lengths of scales. Even if the future development goes to the limit of equal axle loads for both types, the resulting over-loads will be more nearly uniform for scales of different lengths than if a constant load factor is used. This is shown by examination of columns 7, 8, and 9 of Table A. These columns show the percentages of over-load resulting from what may be considered the maximum probable development in car loads on scales designed using various load factors. The extreme variation of the over-load percentage is only 13 where the correct load factors are used, while it is 41 with the constant factor 0.25, and 34 with the constant factor 0.30 which has been suggested.

(4) The standard superstructure sections recommended in the report are consistent with and based upon this method.

In Table No. 1 of the Committee's report the weighbridge girders are proportioned for representative car loads (column 8) figured back from the section capacities, taking dead load into account. The girders are properly proportioned for the scales of which they form a part; they would not be if they were proportioned for the car load derived from the section capacities premised and the constant factor 0.25 proposed.

(5) Economy and conservation of effort demand the use of a few standard designs rather than a multiplicity of individual fancies, and this method lends itself to that end.

The battle of the rail sections has been re-enacted recently with the manufacturers and the purchasers of scales as the opposing forces. It may be said still to be in progress. The peace offer in the form of three standard patterns seems to the writer an acceptable one. It offers, for any desired length, a choice of three capacities. For example, for a 51 ft. scale, the purchaser would have the option of 86, 109, and 148 tons capacity. Inasmuch as the fixing of the capacity desired involves considerable speculation as to the future needs, the range offered seems adequate. The objection that the capacity desired has no relation to the length desired is a pertinent one, but is met by the fact that all reasonable requirements are filled by the selection offered except those for scales of very heavy capacity in conjunction with great length. Such long and heavy scales would be of infrequent demand and may be considered special.

A better range of choice would be offered by, say, four sizes with section capacities of 60, 75, 90, and 105 tons. These sizes would vary from each other by uniform intervals and would enable a purchaser more nearly to fit his requirements. This suggestion does not depart from the principle of standard sections, but rather emphasizes it.

CONCLUSION.

Inasmuch as the definition of capacity provides for correct design without mention of load factors and load factors are not mentioned elsewhere in the specifications, the omission of all of Article 3 (a) following the first paragraph would remove all inconsistency and ground for controversy.

The addition of some matter giving information as to the use and development of load factors and representative car loads and the use of standard scale sections would be informative and a help to the purchaser, but would not affect the principles or requirements embodied in the specifications.

REPORT OF COMMITTEE XX—ON UNIFORM GENERAL CONTRACT FORMS.

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S. D. BRADY,
O. P. CHAMBERLAIN,
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C. J. PARKER,

Committee.

To the American Railway Engineering Association:

Your Committee on Uniform General Contract Forms begs to submit the following report:

The Committee, as its work for the year 1917, received instructions as follows:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.
2. Report on Form of Agreement for Industry Track.
3. Report on Forms of Agreements for Interlocking, and Railway Crossings, conferring with Committee on Signals and Interlocking, including rights and obligations of the interested companies.
4. Report on Form of Agreement embodying rules governing the construction of undercrossings of railways with electrical conductors, conduits, pipe lines and drains, conferring with Committee on Roadway and Committee on Electricity. (See work done for State Public Utilities Commission of Illinois.)
5. Report on Form of Lease Agreement for Industrial Site.

(1) REVISION OF MANUAL.

The Committee has no recommendation as to changes in the subject-matter now in the Manual under the heading "Uniform General Contract Forms."

(2) REPORT ON FORM OF AGREEMENT FOR INDUSTRY TRACK.

The preparation of a Form of Agreement for Industry Track has recently become a matter of interest and attention before a number of different railway associations. Your Committee learned that it has been the subject of consideration of a Committee of the Railway Development Association, composed of representatives of Industrial Departments of Railroads, for quite an extended period. It has also recently been under consideration by other associations, including the General Managers' Association of New York, and by the Presidents and Executives of the railroads centering in Chicago.

Members of our Committee present at its first meeting of the current season in New York City felt that an effort should be made to secure joint action between the Railway Development Association and our Association relative to the preparation of a standard Form of Agreement for Industry Track. Arrangements were therefore made for joint meetings of committees of the two associations. Three such meetings have been held and the Form herewith submitted has been agreed upon by the two Committees for recommendation to their respective associations.

Members of the Association will note, in the form of agreement submitted in Appendix B, that no specific provisions relative to the bargain to be made between the Railroad Company and the Shipper as to division of expense, or ownership of track, have been incorporated in the proposed Form of Agreement. These are left open, for insertion at the option of each Railroad Company, following the lines of the general policy which it may adopt relative to these matters.

A recommendation as to the general policy to be adopted by the railroads is appended to the agreement. The tendency at the present time is undoubtedly toward requiring the Shipper to bear all the expense of the construction and maintenance of the industry track beyond the clearance line, while retaining in the Railroad Company the ownership of that portion of the track located upon its right-of-way. This general policy has already been adopted in many parts of the country, while in others the railroad companies have not yet been able to entirely agree upon it. Its uniform adoption, however, in so far as practicable, is recommended for the whole country by members of the two committees acting as a Joint Committee.

(3) REPORT ON FORM OF AGREEMENT FOR INTERLOCKING PLANT.

Your Committee considered this Form of Agreement at three of its meetings, and also discussed it with a Sub-Committee of the Signal and Interlocking Committee of the Association. The Form of Agreement for Interlocking Plant herewith submitted is the result of action taken at these various meetings.

Members of the Association will note that in the submitted Form of Agreement no attempt has been made to specify a basis upon which the expense for construction, maintenance and operation should be divided, because that portion of the agreement is part of the consideration which must be determined in each case by negotiation between the companies interested; and because conditions vary so widely in different parts of the country that no specific basis for apportioning the expense has been considered feasible. This portion of the agreement is therefore left open to be negotiated and written into the agreement in each case.

The articles covering *Liability* and *Arbitration* are incorporated in the submitted Form, in order to complete the same. The Committee recognizes the fact, as will doubtless also members of the Association, that these two articles are peculiarly the province of the Legal officers of the railroads, and that they will therefore probably be modified in many cases, to meet local conditions, et cetera.

(3-A) REPORT ON FORM OF AGREEMENT FOR RAILROAD CROSSING.

A very considerable amount of work has been done in connection with the preparation of this Form of Agreement by members of the Committee, but the Form is not yet ready for submission to the Convention, and your Committee therefore wishes to report progress.

(4) REPORT ON FORM OF AGREEMENT EMBODYING RULES GOVERNING CONSTRUCTION OF UNDERCROSSING OF RAILWAYS WITH ELECTRICAL CONDUCTORS, CONDUITS, ETC., and

(5) REPORT ON FORM OF LEASE AGREEMENT FOR INDUSTRIAL SITE.

The attention of the Committee has been so fully occupied with other Forms of Agreement that it has been unable during the current year to give these forms consideration, and it is therefore our recommendation that these subjects be reassigned for future consideration.

Respectfully submitted,

THE COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

Appendix A.

A. B. & C. Railroad Company.

INDUSTRY TRACK AGREEMENT.

THIS AGREEMENT, made this.....day of......in the year...... by and between..
....
....
party of the first part, hereinafter called the Railroad Company, and....
....
....
party of the second part, hereinafter called the Shipper:

WITNESSETH:

WHEREAS, the Shipper desires industry track facilities, hereinafter called sidetrack, for the more economical and convenient conduct of its his business, at or near..........................Station, County of.............., State of......................, described as follows:

(Here describe length and exact location of track.)

in accordance with plans dated............................. (Note:—If desired insert "identified by the signature of..........................") hereto attached and hereby made a part hereof; and

WHEREAS, the operation of cars and engines over said sidetrack at other than the regularly established station facilities of the Railroad Company involves the risk of damage to or destruction of property and injury to or death of persons;

Now, therefore, in consideration (Note:—If necessary insert one ($1) dollar, etc.) of the above premises, the covenants and agreements herein contained to be kept and performed by the parties hereto, and of the payments hereinafter to be made, it is mutually agreed that the said sidetrack shall be constructed and maintained, and the Railroad Company hereby agrees to operate the same, under the following terms and conditions:

Right-of-Way.

1. The Shipper shall furnish at $\overset{\text{its}}{\text{his}}$ own expense all necessary right-of-way outside of the right-of-way of the Railroad Company, required for the proper construction and operation of said sidetrack, said right-of-way to be satisfactory to the..............................of the Railroad Company.

The cost and expense of procuring or complying with any ordinance, order, permit or consent whatsoever required by Municipal, State, or other lawfully constituted authorities for the construction, operation, maintenance and use of said sidetrack shall be borne by the Shipper.

During the continuance of this agreement the Railroad Company shall have the right at all times to enter upon the property of the Shipper, for the purpose of constructing, maintaining and operating said sidetrack.

Construction.

2. The actual cost of constructing said sidetrack, including roadbed, trestles, bridges, and all other appurtenances in connection therewith, shall be borne as follows:

(Herein insert details covering terms and conditions as to furnishing labor and material and division of expense as agreed upon.)

(Note:—If desired insert "The Shipper shall also assume the expense of recording this agreement.")

Maintenance.

3. Said sidetrack shall be maintained and renewed to the satisfaction of the............................of the Railroad Company; the work shall be performed and the cost thereof borne as follows:

(Herein insert details.)

Ownership.

4. The title and ownership of said sidetrack shall be vested as follows:

(Herein insert details.)

Use.

5. The Railroad Company shall have the right to use, without cost, the whole or any part of said sidetrack for general railroad purposes, provided such use shall not unreasonably interfere with the use thereof by the Shipper.

The Shipper agrees that $\substack{\text{he}\\\text{it}}$ will not permit or authorize the use of said sidetrack by or for the benefit of any other person, firm or corporation not one of the parties hereto, nor assign this contract or any rights thereunder, without the written consent of the Railroad Company.

Changes or Enlargement.

6. If any change, rearrangement, extension or enlargement of said sidetrack or its structures shall at any time be required by reason of any change in the Railroad Company's track or tracks, or because of any changes in the operating practice of the Railroad, or for any other cause, all expense resulting therefrom shall be borne by the Shipper, unless otherwise mutually agreed by the parties hereto.

Clearances.

7. The Shipper shall not erect nor permit to be erected any building or structure, nor permit any material to be placed above top of rail within............. (......) feet of the nearest rail of said sidetrack on straight track, or within............ (......) feet on curve, nor permit anything to be placed above said sidetrack lower than a height of............ (......) feet above the top of rail.

Accidents.

8. The Shipper agrees to exercise the greatest care in the use of said sidetrack to prevent cars or other obstructions from getting upon or too close to main or other tracks and generally to use such means and care as will avoid accidents of every kind.

Liability.

9. The Shipper hereby agrees to indemnify, protect, and save harmless the Railroad Company for loss of, damage to, or destruction of $^{\text{its}}_{\text{his}}$ property, or the property of any other person or persons upon the premises of the Shipper by $^{\text{its}}_{\text{his}}$ request or consent, whether by fire or otherwise, or of death or injury to any person or persons (except where it can be shown that such death or injury to person or persons was due solely to negligence on the part of employees of the Railroad Company) arising out of the construction, maintenance, use or operation of said sidetrack.

Discontinuance.

10. The Shipper shall assume and bear any and all loss or damage sustained by $^{\text{him}}_{\text{it}}$ in consequence of any temporary or permanent elimination of said sidetrack, due to the relocation or change in the grade of the track or tracks of the Railroad Company by virtue of any municipal action or otherwise, or in event the disposition of the property of the Railroad Company or its future use or development shall make it impracticable in the judgment of the.................of the Railroad Company to continue the connection, and the Shipper hereby waives any and all claims therefor.

Cancellation, Termination and Removal.

11. It is expressly understood and agreed that if for the space of........consecutive months said plant be not operated, unless prevented by a strike or strikes, or if the title to said plant become vested in or the operation thereof be transferred to some party other than the Shipper, or if any other party operating said plant refuses to adopt this agreement and to agree in writing to be bound thereby, or if the Shipper fails to keep and perform any of the covenants, agreements, terms, or condition, hereinbefore set forth to be by $^{\text{him}}_{\text{it}}$ kept and performed, then the Railroad Company reserves the right to terminate this agreement upon............days' written notice to the Shipper.

Upon termination of this agreement the Railroad Company shall have the right to enter upon the property of the Shipper and take up and remove any or all of the material owned by the Railroad Company as aforesaid, and shall not be liable to account in any way to anyone for any monies paid or expended on account of any of the track or tracks covered by this agreement, nor for any damages resulting from the removal of the track or tracks owned by the Railroad Company as aforesaid.

Until terminated as hereinbefore provided, this agreement shall inure to the benefit of and be binding upon the parties hereto, their heirs, executors, administrators, successors and assigns.

IN WITNESS WHEREOF, the parties hereto have executed this agreement in........the day and year first above written.

..................Railroad Company

By..............................

Witness for Railroad Company

....

(Shipper)..........................

By..............................

Witness for Shipper

....

Appendix B.

RECOMMENDATION.

BASIS FOR DIVISION OF COST OF CONSTRUCTION AND MAINTENANCE, AND OWNERSHIP OF INDUSTRY TRACKS.

After leaving the right-of-way of the Railroad Company, all responsibilities of the Company as a common carrier cease and in going beyond the right-of-way, the Railroad Company becomes the Agent of the Shipper in the operation of said sidetrack, thereby contributing to the economical operation and efficiency of its plant. This fundamental principle should, therefore, be considered in determining the basis for dividing the cost of construction and maintenance, and the ownership of such industry track.

An industrial sidetrack is essentially a plant facility and furnishes the shipper with service elsewhere than at the regular station of the Railroad Company. It is, therefore, recommended, as a matter of equity, in constructing such track, that the following terms as to division of expense and the ownership of property, should govern:

1. The Railroad Company may pay for and shall maintain that portion of the sidetrack from the switch point to the clearance point.
2. The Shipper shall pay for and maintain that portion of the sidetrack beyond the clearance point, including roadbed, trestles, bridges and all other appurtenances.
3. That portion of the sidetrack upon the right-of-way of the Railroad Company shall be and remain the property of the Railroad Company.
4. That portion of the sidetrack beyond the right-of-way of the Railroad Company shall be and remain the property of the Shipper,

AGREEMENT FOR INTERLOCKING PLANT.

THIS AGREEMENT, made this............day of..........., 19..
by and between...
hereinafter called the...COMPANY
and ....
hereinafter called the...COMPANY

WITNESSETH THAT:

WHEREAS, (Note:—Include brief description of conditions, including the location of existing or proposed grade crossing; an enumeration of all existing agreements, if any; the names of the companies between which agreements were made, their dates, purpose, et cetera.)

WHEREAS, the parties hereto mutually desire to construct, maintain, renew and operate an interlocking plant at said crossing, the location of said crossing being shown, and the said interlocking plant to be arranged as shown on the blue print marked "Exhibit A", dated........
...., identified by the signatures
of the.........................of the.........................Company,
and of the.......................of the.........................Company,
hereto attached, and hereby made a part of this agreement,

NOW THEREFORE, in consideration of the premises and of the mutual conditions and agreements hereinafter set forth, the parties hereto do covenant and agree as follows:

Definition.

1. The term Interlocking Plant, herein contained, shall be held and taken to include any and all houses, towers, power plants, machinery, appliances and appurtenances required for the operation of the same.

Construction.

2. The................Company agrees to construct an interlocking plant, as shown on said "Exhibit A," and in accordance with specifications which have been approved by the..............of the parties hereto, and identified by their signatures.

The cost of removing any existing safety appliances or devices shall be divided in like manner as the maintenance and renewal expense of said appliances or devices has heretofore been divided.

The..................Company agrees to begin the construction of said interlocking plant within............days after the execution of this agreement, and to carry the same forward to a prompt completion.

(Note:—Insert penalty clause if desired.)

Apportionment of Cost.

3. (a) The cost of constructing, maintaining and renewing said interlocking plant, as shown on said "Exhibit A," shall be borne by the parties hereto as follows:

Each party hereto shall participate in the ownership of said interlocking plant in the ratio which the payments made by it for construction of said interlocking plant, including extensions and changes chargeable to capital account, bear to the total cost of construction thereof.

The expense of maintaining and renewing said interlocking plant shall include taxes, assessments and insurance; all losses by fire, flood or other damage caused by the elements; also any change made necessary by an act, law, or ordinance, of a lawfully constituted public authority.

(b) The cost of operating said interlocking plant, including power, heat, light, and supplies, shall be borne by the parties hereto as follows:

Spare Space.

4. Spare levers, machine spaces, and building space, may be provided for its exclusive use upon request of either of the parties hereto, at the sole cost and expense of such party; provided further, that the other party to this agreement may hereafter acquire the right to the exclusive use of the same by either paying the original cost, or by providing an equal amount of space of the kind used when the same shall be required, at the election of the party which originally provided the spare space.

Extensions and Changes.

5. Either party shall have the right to make extensions or changes in said interlocking plant, provided that they shall not materially impair the efficiency of the same. All such extensions or changes, arising from changes made in any existing track or tracks, or made to cover any future track or tracks or connections, which either party hereto may have the right to construct, or which may be required by reason of any changes made in the standard appliances of either party, or which may be ordered by a lawfully constituted public authority, shall be made by the .... Company, and the cost of such extensions or charges shall be borne by the party hereto for whose benefit said extensions or changes are made, and the amount chargeable to each party for maintenance, renewal and operation in such case shall be determined as follows:

Control of Plant.

6. *Maintenance.*—(a) The maintenance and renewal of said interlocking plant shall be under the sole charge and control of the.......... Company, and it shall employ competent persons to maintain and renew the same, and such parties from time to time so employed shall be removed for good and sufficient reason upon request in writing of a general managing officer of the .... Company.

Each of the parties hereto, through its authorized employes and representatives, shall have the right at all times to inspect said interlocking plant, as well as the accounts covering the construction, maintenance, renewal and operation of the same; and in the event that the .... Company shall notify the .... Company in writing of renewals and repairs that may be necessary for the safe and proper operation of said interlocking plant, and if the .... Company neglects for a period of thirty days to make said necessary renewals and repairs, then the .... Company shall have the right to make such renewals and repairs, and the .... Company shall, upon presentation of proper bills, and within the time provided in Section Ten hereof, pay its proportion of the amount so expended.

(b) Each of the parties hereto shall, at its own expense, keep all switches and derails in its own tracks free from ice, snow, dirt or other obstructions which may interfere in any way with the proper working of said interlocking plant; and in case either party fails to do so, the other party may enter upon the premises of the party at fault and remove such ice, snow, dirt or other obstructions; in which event, the party at fault shall reimburse the party doing such work, as provided in Section Ten hereof, for all expense thereby incurred.

Operation.—(c) The operation of said interlocking plant shall be under the sole charge and control of the .... Company, and it shall employ competent persons to operate the same, and such persons from time to time so employed shall be removed for good and sufficient reasons upon request in writing of a general managing officer of the .... Company.

It is further mutually understood that either party may use the operators at said interlocking plant in its telegraph or telephone service, provided said party shall give the other party at least ten days' prior written notice of the same; but in the event that additional expense is so incurred, either on account of increased wages of operators over levermen, or on account of additional employes required, the party using the operators in its service shall bear the additional expense. If for any reason it becomes necessary to temporarily take the said interlocking plant out of service, the control of the flagmen required to protect said grade crossing shall also be in the .... Company, and the expense of said flagmen shall be considered, for the purpose of apportionment, as an expense of operating said interlocking plant.

Material and Labor Supplied by Parties.

7. Each of the parties hereto shall, without cost to the other, furnish and install its own derails, switch points, switch rods, special switch and derail ties and timbers, all track insulations, poles, cross-arms, pins and insulators, and will maintain and renew them from time to time thereafter; likewise, without cost to the other party, do all the track work and grading along its own tracks necessary to prepare the same for the installation of said interlocking plant, and also provide and maintain proper drainage; likewise, bear the cost and expense of raising and adjusting pipe carrier and mechanism foundations, or the renewal of

detector bars, clips or any other appliances required or made necessary by the resurfacing, reballasting or rail renewal of its tracks within the limits of said interlocking plant; likewise, furnish and install at its own expense any signal bridges, or other special signal supports, which may be required to support signals governing the movement of trains on its tracks.

Either party shall have the right to carry its automatic block signaling through the limits of the interlocking plant at its own expense. Where signals perform the function of both block and interlocking signals, the party hereto whose train movements are controlled by said block signals shall maintain the same at its expense.

Precedence.

8. In the use of said interlocking plant passenger, mail and express trains shall have precedence over freight trains and light engines; and freight trains shall have precedence over light engines. The trains and engines of the .... Company shall have precedence over the trains and engines of like class of the .... Company.

Wage Rates.

9. The wages of employes connected with maintenance, renewal and operation of said interlocking plant shall be the same as the standard wages paid by the .... Company for similar service to its other employes in the same territory.

Payment of Bills.

10. All payments hereunder shall be made within thirty days after rendition of proper bills.

The .... Company shall render bills covering the cost of constructing said interlocking plant, such expense to be billed in one statement unless otherwise agreed upon by the parties hereto.

Bills covering the operation, maintenance and renewal of said interlocking plant shall be rendered monthly; and those covering insurance, taxes and assessments, annually.

Such of said bills as are based upon payroll cost of labor and stock prices of material shall include a fair arbitrary charge to cover supervision, inspection, handling, transportation, accounting and similar undistributed items of expense. Such fair arbitrary charge shall be in accordance with the recommendations of the General Managers' Association of ...., in effect from time to time, or in the absence of any such recommendations, shall be agreed to by the parties, or determined by arbitration as hereinafter provided.

Should dispute arise as to the correctness of any items included in bills rendered under this agreement, the party against which such bills are rendered shall pay all items concerning which there is no dispute, and the other items shall be paid promptly when the correctness thereof has been ascertained by arbitration or otherwise.

Liability.

11. Each party hereto assumes for itself the responsibility and risk of using and operating its own trains and engines over the space covered by the said interlocking system, and also responsibility for the negligent acts and omissions or the alleged negligent acts or omissions of its own officers, agents, servants and employes engaged in connection therewith; and in performance of any of its separate duties under this contract; and will pay to the other party and to third persons all damages which may arise and for which it may be liable arising from such negligence and in such operation.

The party having special charge of the management and operation of said interlocking system shall not be liable to the other party for the negligent acts or omissions, or the alleged negligent acts or omissions of any person employed in the operation, maintenance or repair of said interlocking mechanism, but all persons so employed shall, as respects any injury caused by such negligence, be regarded and treated as the agents or servants of each party hereto, and each of said parties hereby assumes the responsibility for all damages resulting from the negligence of such agents or servants in the operation of its own engines, cars and trains, and those of its tenants, lessees and licensees, at the said crossings, and shall indemnify and save the other party harmless therefrom. Any expense caused or growing out of the injury of any workman or employe engaged upon the construction of said interlocking plant shall be held and considered to be a construction expense, and shall be divided as herein in Section 3 provided.

Arbitration.

12. In case of any differences or dispute arising under this agreement or concerning the subject-matter thereof, the parties hereto agree to submit such difference or dispute to three arbitrators, one of whom shall be appointed by the .... Company, and another by the .... Company, and each party shall give to the other party written notice of appointment of its arbitrator, together with his name and address. The two arbitrators so chosen shall select a third arbitrator. If either party shall fail to choose an arbitrator as herein provided, the arbitrator selected by the other party hereto, at the expiration of .... days after the date of its said written notice, shall select a second arbitrator, and the two arbitrators so chosen shall select a third arbitrator. If within .... days after the appointment of a second arbitrator, as herein provided, the two so chosen shall have failed to select a third arbitrator, either party hereto may apply to any judge of the District Court of the United States for the District which shall then include ...., or
....,
who shall thereupon appoint the third arbitrator. The three arbitrators

so chosen in any manner as herein provided, or a majority of them, shall hear and decide said difference or dispute, and their decision, or that of a majority of them, shall be final and binding on the parties hereto.

The expense of an arbitration under the terms hereof shall be borne by the parties hereto in the proportions fixed by the arbitrators.

Cancellation of Conflicting Agreements.

13. It is mutually understood and agreed that any and all agreements existing between the parties hereto or their predecessors, so far as they conflict, or are inconsistent with the terms and conditions of this agreement, are hereby annulled, but in all other respects they shall continue in full force and effect.

Duration and Succession.

14. This agreement shall take effect on the.................days of ...., 19...., and shall continue in force during the existence and operation of the interlocking plant, or until discontinued by the mutual agreement of the parties hereto.

The provisions of this agreement shall be binding upon and inure to the benefit of the parties hereto, their successors, lessees and assigns.

IN WITNESS WHEREOF, the parties hereto have caused this agreement to be executed in duplicate, by their respective officers, thereunto duly authorized, the day and year first above written.

....	..................................Company,
Secretary.	By....................................
....	..................................Company,
Secretary.	By....................................

REPORT OF COMMITTEE III—ON TIES.

F. R. LAYNG, *Chairman;*
C. C. ALBRIGHT,
W. C. BAISINGER,
M. S. BLAIKLOCK,
THEO. BLOECHER,
F. BOARDMAN,
W. J. BURTON,
W. A. CLARK,
S. B. CLEMENT,
E. L. CRUGAR,

H. S. WILGUS, *Vice-Chairman;*
L. A. DOWNS,
G. F. HAND,
L. C. HARTLEY,
E. D. JACKSON,
J. B. MYERS,
A. J. NEAFIE,
R. R. PAINE,
G. P. PALMER,
LOUIS YAGER,

Committee.

To the American Railway Engineering Association:

The following subjects were assigned your Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Continue the study of effect of design of tie plates and track spikes on the durability of cross-ties.
3. Report on methods in use by various railways for controlling tie renewals.
4. Recommend proper dimensions for cross-ties.
5. Report results of investigation of Forms M. W. 301, 302, 303 and 304, Statistics of Cross-Ties, to see if they are in general use on membership lines.
6. Report on trials of substitute ties.

The work was divided into Sub-Committees, as follows:

(1) F. R. Layng, Chairman; W. A. Clark, L. A. Downs, E. D. Jackson, L. C. Hartley, H. S. Wilgus.

(2) E. D. Jackson, Chairman; M. S. Blaiklock, F. Boardman, G. F. Hand, J. B. Myers, A. J. Neafie.

(3) W. A. Clark, Chairman; W. C. Baisinger, W. J. Burton, R. R. Paine, Louis Yager.

(4) L. C. Hartley, Chairman; W. C. Baisinger, G. P. Palmer.

(5) L. A. Downs, Chairman; E. L. Crugar.

(6) H. S. Wilgus, Chairman; C. C. Albright, Theo. Bloecher, S. B. Clement.

(1) REVISION OF MANUAL.

The Committee recommends that forms M. W. 301, 302, 303 and 304 be withdrawn from the Manual. The report of Sub-Committee (5) shows that these forms are not being used.

(2) EFFECT OF THE DESIGN OF TIE PLATES AND TRACK SPIKES ON THE DURABILITY OF TIES.

This Committee reports progress and suggests that the study of this subject be continued.

(3) REPORT ON METHODS IN USE BY VARIOUS RAILWAYS FOR CONTROLLING TIE RENEWALS.

The Committee submits as information, the report on Subject (3). The following questions were sent to all the principal railroads, represented in the Association:

Subject: "Methods in Use for Controlling Tie Renewals."

1. Who originates the data on which the estimates of tie renewals are based?
2. Are these estimates based on
   (a) Detailed inspection of the entire track, or,
   (b) Detailed inspection of portions of the track, or,
   (c) Tie renewal statistics, or,
   (d) Otherwise?
3. Are these estimates checked independently in the field, in whole or in part?
4. By whom are these estimates revised before approval?
5. Are individual ties designated to be renewed, or is the estimate merely to determine the number of ties required for renewals?
6. What latitude, if any, is allowed the Section Foreman in deviating from the approved inspection?
7. What check is made of the Section Foreman's work?
8. Please submit any general instructions you may have covering tie renewals.

Replies were received from 100 railroads, with an aggregate mileage of 223,000. A tabulation of these replies is appended to this report.

As of interest, but not in any way indicating the recommendations of the Committee, a summary, based on this tabulation, is given below:

	Per Cent. of Total Number of Roads Reporting	*Per Cent. of Total Mileage of Roads Reporting*
Renewals based primarily on detail inspection of track	89	92
Renewals based partly or exclusively on tie renewal statistics	16	14
Renewals based exclusively on tie renewal statistics	9	4
Detail inspection made by Section Foremen	58	54
Detail inspection made by others than Section Foremen	33	42
Individual ties for renewal designated by spots or otherwise	38	52
Individual ties for renewal not designated	62	48
Section Foremen limited in renewals to ties authorized except such additional as are required for safety	67	67
Section Foremen not limited in renewals to those authorized	33	33
Work of making renewals checked by Roadmaster (or Supervisor)	77	74
Work of making renewals checked by others than Roadmaster (or Supervisor)	33	19

The Committee wishes to point out that the method in most general use is not necessarily the best, and that methods may very properly differ on different roads, depending upon the organization, physical conditions, and other factors.

A study of the replies shows that all roads depend largely upon an inspection of ties removed for the purpose of checking renewals. A majority of the roads place the principal responsibility for renewals upon the Section Foreman, while a considerable number place this responsibility primarily upon an inspector working independently of the Section Foreman. The other variations in method represent individual opinions as to the best method of checking the original source of information. This checking takes the form of an independent review of the original check in the field and also checking same against statistics. (See Appendix A.)

(4) RECOMMEND PROPER DIMENSIONS FOR CROSS-TIES.

The Committee reports progress and suggests that a study of this subject be continued.

(5) USE OF FORMS M. W. 301, 302, 303, 304.

The membership lines were asked as to their use of these forms and one hundred replies, representing 232,026 miles, were received. Not a single road is using them and but twelve, representing approximately 10,521 miles, contemplate doing so. (See Appendix B.)

(6) REPORT ON TRIALS OF SUBSTITUTE TIES.

The attention of the Association is called to a very valuable publication issued by the United States Department of Agriculture, Forest Service, H. S. Graves, Forester, as follows:

"Guide Book for the Identification of Woods Used in Ties and Timbers," by Arthur Koehler. The book may be obtained from the department at Washington.

The information furnished by the various railroads using substitute ties is abstracted as usual, and the results to date are shown on the tabulated statement. This statement is intended to include all installations on steam railroads in America reported to the Association, and is thought to cover practically all substitute ties used so far in this country. (See Appendix C.)

CONCLUSIONS.

(1) Your Committee recommends that forms Nos. M. W. 300, 301, 302, 303, 304 be withdrawn from the Manual.

(2) That the report as to methods in use by various railroads for controlling tie renewals be received as information.

(3) That the report on substitute ties be received as information.

Respectfully submitted,

THE COMMITTEE ON TIES.

Appendix A.

METHODS FOR CONTROLLING TIE RENEWALS.

W. A. Clark, Chairman, Sub-Committee.

	1	2	3	4	5	6	7	8
Name of Railroad	Origin of Data for Tie Renewals	Estimates Based on	Estimates Checked Independently in Field	By Whom Are Estimates Revised Before Approval	Are Individual Ties Designated to Be Renewed at Time Estimates Are Made	What Latitude Is Allowed Section Foremen in Deviating From Approved Inspection	What Check Is Made of Section Foremen's Work	General Remarks
Algoma Central & Hudson Bay	Section foreman.	Detailed inspection portions of track.	By Roadmaster.	By Roadmaster.	No.	Considerable latitude with Roadmaster's approval.	Roadmaster's supervision.	Roadmaster handles subject of tie renewals.
Atchison, Topeka & Santa Fe..	Section foreman.	Detailed inspection of entire track.	In part by Roadmaster.	By Roadmaster, Division Engineer and Superintendent.	No.	Permit additional renewals where necessary.	Ties removed checked by Roadmaster.	Subject covered by General Maintenance rule.
Atlantic Coast Line	Roadmaster.	Detailed inspection entire track.	No.	By Gen'l Roadmaster and Eng. M. of W. and Chief Engineer on basis statistics.	No.	Can renew unsafe ties regardless of estimate.	Ties removed checked by Roadmaster.	Estimates adjusted by General Roadmaster on Chief Engineer's approval.
Baltimore & Ohio............	Preliminary estimate by Engineer of M. of W.	Renewal estimates on detailed inspection entire track.	Abnormal conditions by supervision, tie inspector, division and district Engineer and general tie inspector.	By Division Engineer, district Engineer and Engineer of M. of W.	No; but spotted for renewal.	Can renew unsafe ties regardless of estimate.	Ties removed checked by tie inspector.	Subject under close supervision engineer department with pointed detailed instructions.
Bangor & Aroostook...........	Section Foremen and Roadmasters	Detailed inspection entire track checked by statistics.	By roadmasters in part.	Maintenance engineer.	Yes.	Limited to approval of roadmaster.	Checked by roadmaster.	....
Bessemer & Lake Erie.........	Section foreman.	Detailed inspection entire track.	In part by supervisor.	By engineer of track.	Yes.	Can renew unsafe ties regardless of estimate.	Ties removed checked by supervisor.	....
Bingham & Garfield..........	Section foreman.	Detailed inspection entire track.	In part by division engineer and superintendent.	By superintendent, division engineer and chief engineer.	No.	Only with roadmaster's approval.	Checked by roadmaster.	....

Boston & Albany.............	Section foreman.	Detailed inspection entire track.	In part.	By supervisor and division engineer.	No.	By approval of supervisor.	Checked by supervisor and division engineer.	Renewals governed by detailed printed instructions.
Buffalo, Rochester & Pittsburgh	Tie inspector.	Detailed inspection entire track.	In part by division engineer and roadmaster.	Not revised.	Yes.	By approval of roadmaster.	Checked by inspectors and division officers.	Renewals governed by detailed printed instructions.
Butte, Anaconda & Pacific.....	Supt. M. of W. & S.	Detailed inspection entire track.	No.	No.	No.	Considerable latitude.	Checked by Supt. M. of W. & S.	....
Canadian Government Rys....	Roadmaster and section foreman.	Detailed inspection entire track.	In part by resident and division engineers.	By resident and division engineers.	Yes.	Only with approval of roadmaster	Checked by resident and division engineers.	Renewals governed by detailed printed instructions.
Canadian Nor. (Eastern Lines).	Section foreman.	Detailed inspection entire track.	Yes.	By division engineers and superintendent track.	Yes.	Limited.	Checked by resident and division engineers.	....
Canadian Pacific (Lines West)..	Section foreman. Fall inspection.	Detailed inspection entire track by foreman, and portion track by roadmaster and tie renewal statistics.	Yes; in part.	By Supt., Gen. Supt. and Gen. manager.	No, but spotted at spring inspection.	R equires approval of general manager for additional ties.	Checked by division officers.	....
Canadian Pacific (Lines East)..	Section foremen and roadmasters	Detailed inspection entire track.	Only when estimates are abnormal.	By assistant general manager.	No.	Considerable latitude.	Checked by roadmasters and other officers.	Subject covered by general maintenance rules.
Carolina, Clinchfield & Ohio,..	By roadmaster.	Detailed inspection of portion of track.	In part by general manager from inspection and statistics.	By general manager.	Yes; in part.	Limited latitude.	Checked by roadmaster.	....
Central R. R. of New Jersey...	Section foreman.	Detailed inspection of entire track.	By supervisor.	By supervisor or engineer M. of W.	No.	Limited latitude.	Checked by supervisor.	Subject covered by maintenance rules.
Central of Georgia Railway....	Section foreman and supervisors.	Check of one mile each section by roadmaster, also statistics.	Checked by roadmaster in part.	By engineer M. of W. and general manager.	No.	Considerable latitude as to ties, but held to total allotment.	Checked by supervisor.	....
Chicago & Eastern Illinois.....	Track supervisor.	Section foreman and supervisor, all track.	Supervisor.	Division engineer and chief engineer.	No.	Considerable latitude.	Supervisor, division and chief engineer.	....
Chicago, Rock Island & Pacific.	Roadmaster.	Detailed inspection of entire track.	Yes; variable.	Division and district officials.	No.	Only with approval of division officials.	....	....

METHODS FOR CONTROLLING TIE RENEWALS—Continued.

	1	2	3	4	5	6	7	8
Name of Railroad	Origin of Data for Tie Renewals	Estimates Based on	Estimates Checked Independently in Field	By Whom Are Estimates Revised Before Approval	Are Individual Ties Designated to Be Renewed at Time Estimates Are Made	What Latitude Is Allowed Section Foremen in Deviating From Approved Inspection	What Check Is Made of Section Foremen's Work	General Remarks
Chicago & Alton..............	....	Statistics.	Spring inspection in field.	Any material increase over Fall allowance is approved by chief engineer and general manager.	No.	Reasonable latitude to renew unsafe ties.	Supervisor and roadmaster.	....
Chicago, Burlington & Quincy..	Roadmaster.	Detailed inspection of entire track.	Yes; in part.	Supt., Gen. Supt. and general manager.	Yes.	Reasonable latitude.	Roadmaster and general manager.	Renewals covered by detailed printed instructions.
Chicago, Milwaukee & St. Paul.	Section foreman and roadmasters	Detailed inspection of entire track, also statistics.	No.	Div. Supt., tie agent, Asst. to vice-president.	Yes.	Considerable latitude.	Roadmaster and general officers.	....
Chicago & North Western.....	Roadmasters and superintendents.	Detailed inspection of entire track.	No.	Supt., Asst. Gen. Mgr., Gen. Mgr., Vice-Pres. O.M., President.	Yes.	None.	By roadmaster.	....
Chicago, St. P., Minn. & Omaha	Section foreman.	Detailed inspection of entire track.	Yes; in whole.	Roadmaster.	No.	None as to total number of renewals.	Roadmaster.	....
Chicago Great Western.........	Section foreman and supervisors.	Inspection of entire track and statistics.	In part.	Chief engineer and general manager.	No.	Reasonable latitude.	Supervisor and engineer M. of W.	....
Chicago & Western Indiana....	Section foreman.	Detailed inspection of entire track.	By supervisor.	Engineer M. of W.	No.	Limited latitude.	Supervisor regularly, occasionally by engineer M. of W.	....
Delaware & Hudson...........	Roadmaster.	Entire track by section foreman, portion of track by supervisor.	Yes; in part.	Chief engineer.	No.	Limited latitude.	Supervisor and roadmaster.	....

Del., Lackawanna & Western..	Roadmaster.	Detailed inspection all track by section foreman, supervisor and roadmaster.	By general roadmasters and principal assistant engineer.	By principal assistant engineer.	No.	Limited latitude.	Ties renewed inspected by officers of maintenance department.	Special instructions for renewal of treated ties.
Denver & Rio Grande.........	Section foreman.	Detailed inspection of entire track.	By district roadmaster.	By division superintendent.	No.	Very limited.	By district roadmaster.	....
Duluth & Iron Range Ry. Co..	Section foreman.	Detailed inspection of entire track.	In part by roadmaster.	Roadmaster and chief engineer.	No.	Limited to number of ties approval of roadmaster.	By roadmaster.	....
Duluth, Missabe & Northern...	Section foreman.	Detailed inspection of entire track.	By roadmaster in part.	Roadmaster and chief engineer.	No.	Considerable latitude.	By roadmaster.	....
Duluth, South Shore & Atlantic	Section foreman.	Detailed inspection of entire track.	By roadmaster.	General roadmaster.	Yes.	Considerable latitude.	By roadmaster.	....
Elgin, Joliet & Eastern.........	Section foreman.	Detailed inspection of entire track.	By roadmaster and assistant chief engineer.	By assistant chief engineer.	No.	Limited latitude.	By roadmaster.	....
El Paso & Southwestern.......	Roadmaster.	Detailed inspection of entire track.	No.	Resident engineer and chief engineer M. of W.	No.	Limited to approval of roadmaster	By roadmaster.	....
Erie Ry. Co..................	Supervisor.	Detailed inspection of entire track.	In part by division engineer and superintendent of maintenance.	Division engineer and superintendent of maintenance.	Yes.	None.	By supervisor reporting facts to division engineer	....
Fort Worth & Denver City....	Roadmaster.	Detailed inspection of entire track.	Yes; in part.	Supt., Gen. Supt. and chief engineer.	No.	Considerable latitude.	By roadmaster.	....
Grand Trunk Ry. System.....	Section foreman.	Detailed inspection of entire track.	By supervisor in part.	By superintendent of track.	Yes.	None.	By supervisor.	....
Great Northern..............	Tie inspector.	Detailed inspection of entire track.	In part.	Engineer M. of Way.	Yes.	Limited latitude.	By roadmaster.	....
Gulf Coast Lines.............	Section foreman.	Detailed inspection of entire track, also statistics.	No.	Superintendent.	No.	Considerable latitude.	By division roadmaster and division superintendent.	....
Hocking Valley...............	Engineer M. of W.	Renewal statistics	No.	Chief engineer.	No.	Generous latitude.	By supervisor.	....
Illinois Central..............	Section foreman.	Detailed inspection of entire track and statistics.	By supervisor in whole and roadmaster in part.	Engineer M. of W.	No.	Limited to approval by supervisor.	Ties renewed inspected by division officers.	....

METHODS FOR CONTROLLING TIE RENEWALS—Continued.

Name of Railroad	1 Origin of Data for Tie Renewals	2 Estimates Based on	3 Estimates Checked Independently in Field	4 By Whom Are Estimates Revised Before Approval	5 Are Individual Ties Designated to Be Renewed at Time Estimates Are Made	6 What Latitude Is Allowed Section Foremen in Deviating From Approved Inspection	7 What Check Is Made of Section Foremen's Work	8 General Remarks
Indiana Harbor Belt...........	Roadmaster.	Renewal statistics	No.	Engineer M. of W.	No.	Liberal latitude.	By roadmaster.	....
International & Great Northern	Section foreman.	Detailed inspection of entire track.	Yes; in part.	Roadmaster.	No.	Limited latitude.	By roadmaster.	....
Kanawha & Michigan.........	Section foreman.	Detailed inspection of entire track.	By supervisor.	Engineer M. of W., general superintendent and vice-president.	No.	Limited latitude.	By supervisor.	....
Kansas City Southern Ry. Co.	Section foreman and roadmaster.	Detailed inspection of entire track, also statistics.	No.	By chief engineer.	No.	Wide latitude.	Checked by roadmaster, division engineer or chief engineer.	....
Lake Superior & Ishpeming Ry.	Section foreman.	Detailed inspection of entire track.	In part.	Roadmaster and chief engineer.	No.	Limited latitude.	Checked by roadmaster.	....
Lehigh & New England........	Section foreman.	Detailed inspection of entire track and statistics.	By supervisor.	Engineer M. of W.	No.	Limited latitude.	Checked by supervisor.	....
Lehigh Valley................	Track supervisor.	General inspection of entire track.	In part.	Ry. Div. Eng. and Engr. M. of W.	No.	Limited latitude.	Checked by supervisor and division engineer.	....
Long Island..................	Section foreman.	Detailed inspection of entire track.	In part.	Supervisor.	Yes.	Limited by supervisor's approval.	Checked by supervisor.	....
Louisiana & Arkansas.........	Tie inspector.	Detailed inspection of entire track.	In part by supervisor and others.	By district supervisor and chief engineer.	Yes.	No latitude.	Checked by supervisor.	....
Louisville & Nashville.........	Section foreman.	Detailed inspection of entire track.	By supervisor and checking roadmaster.	By division roadmaster, checking roadmaster and chief engineer.	No.	None.	....	....

Maine Central................	Roadmaster.	Detailed inspection of entire track.	No.	By Engr. M. of W.	Yes.	Limited latitude.	Checked by roadmaster and assistants.	....
Minneapolis, St. P. & Sault Ste. Marie.....................	Section foreman and roadmasters	Detailed inspection of entire track.	In part.	By special roadmaster and superintendents.	Yes.	Limited latitude.	Checked periodically by inspectors.	....
Minneapolis & St. Louis........	Section foreman.	Detailed inspection of entire track.	In whole.	By roadmaster and superintendent.	No.	Wide latitude.	Checked by roadmaster.	....
Missouri, Kansas & Texas......	Roadmaster.	....	No.	By division engineer.	No.	Liberal latitude.	Checked by roadmaster.	....
Missouri Pacific R. R. Co......	Inspectors.	Detailed inspection of entire track.	In part by roadmasters, general roadmaster, engineer M. of W., and assistant engineers.	By general roadmaster and chief engineer.	Yes.	Limited to renewal of broken ties.	Checked by roadmaster and assistant engineers	Printed detailed instructions cover work.
Mobile & Ohio Ry. Co........	Roadmasters and supervisors.	Detailed inspection of entire track.	No.	By superintendent	No.	Limited by supervisor's approval.	Checked by supervisor.	....
Nashville, Chattanooga & St. Louis...................	Section foremen and supervisors.	Detailed inspection of entire track.	No.	By division engineer and roadmaster.	No.	Wide latitude.	Checked by general roadmaster, division engineer and supervisors.	....
New York Central Lines (East)	Track supervisor.	Detailed inspection of entire track.	Yes.	By Engr. M. of W.	No.	Limited to approval of supervisor.	Checked by supervisor or his assistant.	....
New York Central Lines (West)	Section foreman.	Detailed inspection of entire track.	In part.	By supervisor and division engineer	No.	Wide latitude.	Checked by supervisor.	....
New York Central Lines—Big Four..................	Supervisor.	Detailed inspection of entire track.	No.	By division engineer and chief engineer.	No.	Limited to allotment.	Checked by supervisor.	....
New York, Central, Pittsburgh & Lake Erie..........	Section foreman.	Detailed inspection of entire track.	No; except in special cases.	By general foreman, supervisors and engineer M. of W.	No.	Limited to allotment.	Checked by general foreman and supervisor.	....
New York Central, Lake Erie & West	Section foreman.	Detailed inspection of entire track.	By roadmaster.	By roadmaster.	No.	Limited to allotment.	Checked by roadmaster.	....
New York Central, Michigan Central	Section foreman.	Detailed inspection of entire track.	By roadmaster and assistant roadmaster.	By division engineer.	No.	Limited to allotment except with roadmaster's approval.	Checked by roadmaster and division engineer.	....

METHODS FOR CONTROLLING TIE RENEWALS—Continued.

	1	2	3	4	5	6	7	8
Name of Railroad	Origin of Data for Tie Renewals	Estimates Based on	Estimates Checked Independently in Field	By Whom Are Estimates Revised Before Approval	Are Individual Ties Designated to Be Renewed at Time Estimates Are Made	What Latitude Is Allowed Section Foremen in Deviating From Approved Inspection	What Check Is Made of Section Foremen's Work	General Remarks
New York Central, Toledo & Ohio Central	Chief engineer.	Statistics.	General inspection by supervisor.	Chief engineer after suggestions by supervisors and division engineers.	No.	Limited latitude.	Supervision, division engineer and chief engineer.	Work covered by complete printed instructions.
New York, New Haven & Hartford	Section foreman.	Detailed inspection of entire track.	By supervisor.	By engineer M. of Way.	Yes.	Limited to allotment.	By track supervisor.	Work covered by detailed printed instructions.
Norfolk Southern	Section foreman.	Detailed inspection of entire track.	In part by supervisor.	By superintendent M. of W.	No.	Limited latitude.	Checked by supervisor.	....
Norfolk & Western	Section foreman.	Detailed inspection of entire track, also statistics.	By roadmaster in part.	By assistant to general manager	Yes.	Limited latitude.	Checked by assistant engineer of maintenance and assistant general manager.	....
Northern Pacific	Section foreman.	Detailed inspection of entire track, also statistics.	In part by roadmasters and superintendents.	By roadmaster, superintendents and chief engineer M. of W.	Yes.	Limited to direction of roadmaster.	Checked by roadmaster.	Work covered by printed instructions.
Penna. R. R. (Lines East)	Section foreman.	Detailed inspection of entire track.	No.	Supervisor and division engineer.	Yes.	None.	Supervisor.	Printed detailed instructions provided.
Penna. Lines (West)	Section foreman.	Detailed inspection of entire track.	No.	Supervisor and division engineer.	No.	Limited.	Supervisor and division engineer.	Printed detailed instructions provided.
Penna. Lines (West) (St. Louis System)	Section foreman.	Detailed inspection of entire track.	By supervisor.	Division engineer and division superintendent.	No.	Limited.	Supervisor.	....
Pere Marquette Ry.	Selected section foreman.	Detailed inspection of entire track.	No.	Division engineer and roadmaster and chief engineer.	Yes.	Limited to approval of roadmaster and division engineer.	....	....

Peoria & Pekin Union Ry......	Chief engineer.	Statistics.	No.	None.	No.	Limited.	Roadmaster and other officials.	....
Philadelphia & Reading.......	Section foreman and supervisor.	Detailed inspection of entire track.	No.	Division engineers	No.	Limited.	....	....
Pittsburg, Shawmut & Northern Ry. Co............	Roadmaster.	Detailed inspection of entire track.	No.	Engineer M. of W.	Yes.	Liberal.	....	....
Richmond, Fredericksburg & Potomac R. R. Co..........	Section foreman.	Detailed inspection of entire track.	By supervisor	Engineer M. of W.	Yes.	Liberal.	Supervisor.	....
Los Angeles & Salt Lake.......	Section foreman, roadmaster and division engineer.	Detailed inspection of entire track and statistics.	No.	Engineer M. of W.	Yes.	None.	By roadmaster.	....
San Antonio & Aransas Pass Railway....................	Section foreman and roadmaster.	Detailed inspection of entire track.	By M. of W. inspector.	Superintendent M. of W.	No.	Limited.	By roadmaster and inspector M. of W.	....
St. Louis-San Francisco Ry....	Section foreman and roadmaster.	Detailed inspection of track.	No.	Superintendent, general superintendent and general manager.	Yes.	Limited.	By roadmaster.	Printed detailed instructions furnished.
St. Louis Southwestern........	Tie renewal inspector.	Detailed inspection of entire track.	Yes.	General manager.	Yes.	Limited.	By assistant roadmaster.	Printed detailed instructions furnished.
Seaboard Air Line............	Roadmaster.	Detailed inspection of entire track.	No.	Division engineer and engineer M. of W.	No.	Liberal.	By roadmaster and division engineer.	....
Southern Railway............	Roadmaster.	Detailed inspection of entire track.	No.	Engineer M. of W. and chief engineer.	No.	Limited.	Supervisor.	....
Southern Railway (Lines West)	Roadmaster.	Detailed inspection of entire track.	In part by roadmaster.	Engineer M. of W. and chief engineer.	Yes.	Limited.	Supervisor and roadmaster.	....
Southern Pacific Co...........	Assistant Chief engineer.	Statistics.	No.	None.	No.	Limited.	Roadmaster and division engineer	....
Southern Pacific (Sunset Lines)	Section foreman, roadmaster and assistant superintendent.	Detailed inspection and statistics.	Yes.	Engineer M. of W.	No.	Liberal.	Roadmaster.	....
Spokane International.........	Roadmaster.	Detailed inspection of entire track.	Yes.	Superintendent.	No.	Limited.	Roadmaster.	....
Temiskaming & Nor. Ontario..	Section foreman.	Detailed inspection of entire track.	By roadmaster in part.	Chief engineer.	No.	Liberal.	Roadmaster.	....

METHODS FOR CONTROLLING TIE RENEWALS—Continued.

Name of Railroad	1 Origin of Data for Tie Renewals	2 Estimates Based on	3 Estimates Checked Independently in Field	4 By Whom Are Estimates Revised Before Approval	5 Are Individual Ties Designated to Be Renewed at Time Estimates Are Made	6 What Latitude Is Allowed Section Foremen in Deviating From Approved Inspection	7 What Check Is Made of Section Foremen's Work	8 General Remarks
Texas Midland................	Section foreman.	Detailed inspection of entire track.	In whole.	Chief engineer.	Yes.	Limited.	By roadmaster.	....
Toronto, Hamilton & Buffalo..	Section foreman and roadmaster.	Detailed inspection of entire track.	No.	Roadmaster and chief engineer.	No.	Liberal.	By roadmaster.	....
Oregon Short Line............	Section foreman and roadmaster.	Detailed inspection of entire track.	No.	Division engineer M. of W.	No.	Liberal.	By roadmaster.	....
Twin City Rapid Transit Co..	General foreman.	Detailed inspection of entire track.	No.	Engineer M. of W.	No.	Limited.	By roadmaster.	....
Union Pacific System..........	Roadmaster.	Detailed inspection of entire track.	Yes.	General roadmaster and division engineer.	No.	Liberal.	By roadmaster.	....
Union Trac. Co. of Indiana....	Section foreman and division engineer.	Detailed inspection of entire track.	No.	Division engineer.	Yes.	Liberal.	....	....
Virginian.....................	Roadmaster.	Detailed inspection of entire track.	No.	Chief engineer.	Yes.	Liberal.	By roadmaster.	....
Wabash Ry. Co...............	Roadmaster and supervisor.	Detailed inspection of entire track.	In part by engineer M. of W.	Engineer M. of W. and chief engineer M. of W.	Yes.	Liberal.	By supervisor and engineer M. of W.	....
Watauga & Yadkin River Ry..	Track supervisor and section foreman.	Detailed inspection of entire track.	Yes.	Roadmaster.	Yes.	Limited.	By supervisor.	....
Waterloo, Cedar Falls & Nor...	Roadmaster.	Detailed inspection of entire track.	Yes.	Engineer, superintendent.	No.	....	By roadmaster.	....
Western Maryland............	Division engineer.	Statistics.	No.	....	No.	Liberal.	By division engineer.	....
Wheeling & Lake Erie.........	Section foreman.	Detailed inspection of entire track.	No.	Roadmaster.	No.	Limited.	By roadmaster and general roadmaster.	....

Appendix B.

USE OF FORMS M. W. 301, 302, 303, 304.

L. A. Downs, Chairman, Sub-Committee.

Name of Road	Mileage	1	2	3	4	5	6	Reply Made by	Remarks
		Are These Forms Now in Use on Your Road	Have You Ever Made Use of Them	If So, to What Extent	Is It Your Intention to Place Them in Use on Your Road	Have You in Use on Your Road Any Forms Similar to These for Compiling Statistics of Cross Ties	If You Have Such Form Please Attach Copy		
Akron, Canton & Youngstown..	70	....	....	....	....	....	....	....	....
Algoma Central & Hudson Bay	419	....	....	....	....	....	....	....	....
Apalachicola Northern.........	102	No	No	None	No	No	....	R. J. Lockwood, V. P. & G. M.	Use only pine and cypress. Forms too elaborate.
Arizona Extension............	....	....	....	....	....	....	....	....	....
Arkansas & Louisiana Midland.	102	No	No	None	No	....	Attd.	E. Ford, President	Form sent not similar to A R E A forms.
Atchison, Topeka & Santa Fe..	10649	No	No	None	No	Test sections	....	C. F. W. Felt, C. E.	Forms not worth keeping up.
Atlanta, Birmingham & Atlantic	641	No	No	None	....	See note	....	L. L. Beall, Chief Engineer	Keep weekly record of ties renewed per section. Not mile post.
Atlantic Coast Line...........	4577	No	No	None	No	See note	....	J. E. Willoughby, Chief Engineer	Use test sections.
Baltimore & Ohio............	4692	No	No	None	No	No	....	E. Stimson, Engineer M. of W.	Cross tie records are obtained through special test sections.
Bangor & Aroostook..........	625	....	....	....	....	....	....	....	....
Bessemer & Lake Erie.........	209	No	No	None	No	No	....	F. R. Layng, Engineer of Track	
Boston & Albany.............	393	No	No	None	No	No	....	F. B. Freeman, Chief Engineer	Not sufficient force to keep up forms.
Boston & Maine..............	2481	....	....	....	....	....	....	....	....
Buffalo, Rochester & Pittsburg	586	No	No	None	No	See note	....	E. F. Robinson, General Manager	Sent forms in use.
Butte, Anaconda & Pacific.....	76	....	....	....	....	....	....	....	....
Canadian Gov't Railways......	3803	No	No	None	See note	....	....	C. B. Brown, Asst. Gen. Mgr.	Considering use of forms.
(Transcontinental Railway)....	1800								
Canadian Northern...........	7545	....	....	....	....	....	....	....	....
Canadian Pacific.............	12994	No	No	None	No	No	....	J. M. R. Fairbairn, Asst. Chief Engr.	....
Canadian Pacific (West. Lines)		No	No	None	Not in near future	....	....	J. G. Sullivan, Chief Engineer	Tie department kept record ties treated and untreated used on each subdivision each year. Engineer department keep record treated ties on each mile where used.
Carolina, Clinchfield & Ohio...	291	No	See note		....	....	....	O. K. Morgan, Chief Engineer	Line built 1909. No need as yet for record tie renewals.

Central of Georgia	2024	No	No	....	....	....	....	C. E. Weaver, Engineer M. of W.	Just replied "Not in use."
Central New England	304	....	....	....	....	....	....	....	....
Central Railroad of New Jersey	642	No	No	None	No	Yes	Attd.	A. E. Owen, Chief Engineer	Additional labor required to use forms. Forms in use cover only number used various types.
Central Vermont	586	No	No	....	No	....	....	P. D. Fitspatrick, General Roadmaster	....
Chesapeake & Ohio	2371	No	No	None	No	No	Attd.	C. W. Johns, Engr. Br. Lines	Sent copy Form N 43.
Chicago & Alton	1052	No	No	None	See note	No	....	H. T. Douglas, Jr., Chief Engineer	Not sufficient force to use the forms. Hope to use them when normal conditions return.
Chicago & Eastern Illinois	1282	No	No	None	No	No	....	L. C. Hartley, Chief Engineer	....
Chicago & Illinois Western	17	....	....	....	....	....	....	....	....
Chicago & Northwestern	8423	No	No	None	No	Rely on test sections	....	W. H. Finley, Chief Engineer	Not practical to use forms. Better results can be obtained from test sections.
Chicago, Burlington & Quincy	9366	No	No	None	No	Test sections	....	A. W. Newton, Chief Engineer	Use test sections.
Chicago & Western Indiana	77	No	No	None	Not at present	....	Attd.	E. H. Lee, V. P. and Chief Engr.	Attached form in use.
Chicago Great Western	1496	....	....	....	....	....	....	....	....
Chicago, Indianapolis & Louisville	622	No	No	None	No	No	....	A. S. Kent, Chief Engineer	....
Chicago Junction	168	No	No	None	Not at present	No	....	G. W. Hegel, Chief Engineer	....
Chicago, Milwaukee & St. Paul	10287	No	No	None	No	No	....	C. F. Loweth, Chief Engineer	Tried out elaborate system several years ago without success. Does not think forms now using of any value to committee.
Chicago, Rock Island & Pacific	7829	No	No	None	No	Test sections	....	C. A. Morse, Chief Engineer	Could not rely on foremen for correct information. Are now using test sections
Chicago, St. Paul, Minneapolis & Omaha Railway	1753	No	No	....	....	....	....	H. Rettinghouse, Chief Engineer	Just replied "Not in use."
Chicago, Terre Haute & S. E.	374	....	....	....	....	....	....	....	....
Cincinnati, Findlay & Ft. Wayne	91	No	No	None	No	No	....	J. B. Carothers, Receiver	....
Cincinnati, Hamilton & Dayton	1013	....	....	....	....	....	....	....	....
Cincinnati, Indianapolis & West.	381	....	....	....	....	....	....	....	....
Delaware & Hudson Company	916	....	....	....	....	....	....	....	....
Delaware, Lackawanna & West.	996	No	No	None	Yes	No	....	G. J. Ray, Chief Engineer	....
Denver & Rio Grande	2901	No	No	None	No	No	....	J. G. Gwyn, Chief Engineer	....

USE OF FORMS M. W. 301, 302, 303, 304.

Name of Road	Mileage	1	2	3	4	5	6	Reply Made by	Remarks
		Are These Forms Now in Use on Your Road	Have You Ever Made Use of Them	If So, to What Extent	Is It Your Intention to Place Them in Use on Your Road	Have You in Use on Your Road Any Forms Similar to These for Compiling Statistics of Cross Ties	If You Have Such Form Please Attach Copy		
Duluth & Iron Range	205	No	No	None	No	No		W. A. Clark, Chief Engineer	Ties all one kind wood. Benefit from use forms would not pay for keeping up.
Duluth, Missabe & Northern	747								
Duluth, South Shore & Atlantic	747	No	No	None	Yes	No		E. R. Lewis, Chief Engineer	
Duluth, Winnipeg & Pacific	171								
Elgin, Joliet & Eastern	447	No	No	None	No	Time book		A. Montzheimer, Chief Engineer	Attached time book form.
El Paso & Southwestern Sys	1027								
Erie Railroad	2522	No	No	None	No			G. B. Owen, Supt. Maint.	
Florida East Coast	745								
Fla., Johnstown & Gloversville	110								
Fort Smith & Western	259								
Fort Worth & Denver City	454								
Georgia	307								
Grand Trunk Railway System	4790	No	No					H. R. Safford, Chief Engineer	Just started to keep detail record. Does not say what it is.
Grand Trunk Pacific	2748	No	No	None	No			H. H. Brewer, Genl. Supt.	
Great Northern	8102	No	No	None	No	No		A. H. Hogeland, Chief Engineer	Too much clerical work.
Gulf & Ship Island	307								
Hocking Valley	351	No	No	None	No	No		W. Michel, Chief Engineer	
Hudson Bay									
Illinois Central	6149	No	No	None	No	See note		A. S. Baldwin, Chief Engineer	Attached copies of forms 1151, AN 22090, 1195, 1195½.
Illinois Traction System	425	No	No					L. B. Martin, Engineer M. of W.	Just replied "Not in use."
International & Great Northern	1160	No	No	None	No			F. S. Schwinn, Asst. Supt.	
Johnstown & Stony Creek	12								

Kanawha & Michigan..........	175	No	No	None	Yes; Forms 301 and 303	No	....	C. M. McVay, Engineer M. of W.	Use only white and chestnut oak ties.
Kansas City Southern.........	865	No	No	None	No	No	....	J. M. Weir, Chief Engineer	Use only white and red oak ties. Force insufficient to keep forms.
Kansas City Terminal.........	76	No	No	None	Yes	No	....	J. V. Hanna, Chief Engineer	Expects to use forms when maintenance work assumes normal course.
Kentucky & Indiana Terminal.	16	....	....	....	....	....	....	....	....
Lake Shore Electric...........	180	....	....	....	....	....	....	....	....
Lake Superior & Ishpeming... Munising, Marquette & S. E...	172	No	No	None	No	No	Attd.	R. C. Young, Chief Engineer	Forms too long. Attached copy form 13½.
Lehigh & Hudson River.......	97	....	....	....	....	....	....	....	....
Lehigh & New England........	296	....	....	....	....	....	....	....	....
Lehigh Valley................	1442	No	No	None	No	....	....	G. T. Hand, Chief Engineer	....
Long Island..................	397	No	No	None	No	No	....	J. R. Savage, Chief Engineer	Mark ties to show year installed.
Los Angeles & Salt Lake.......	1115	No	No	None	No	No	....	R. K. Brown, Engr. Maint.	....
Louisiana & Arkansas..........	283	No	No	None	No	No	....	F. L. Beal, Chief Engineer	Use only untreated white and post oak ties.
Louisiana & Northwestern.....	121	....	....	....	....	....	....	....	....
Louisville & Nashville.........	5037	No	No	None	No	No	....	W. H. Courtenay, Chief Engineer	....
Maine Central................	1347	No	No	None	No	....	....	G. F. Black, Engr. M. of W.	Says "for some reason" not used.
Midland Valley...............	364	....	....	....	....	....	....	....	....
Minneapolis, St. Paul & Sault Ste. Marie..................	4290	No	No	None	....	....	....	E. A. Whitman, Chief Engineer	Record kept by divisions on main line. Branches and sidings kept separately.
Minneapolis & St. Louis........	1647	No	No	None	No	No	....	J. H. Reinheldt, Chief Engineer	....
Minnesota, Dakota & Western.	40	....	....	....	....	....	....	....	....
Mississippi Central............	164	....	....	....	....	....	....	....	....
Miss. River & Bonne Terre....	65	No	No	None	No	No	....	C. H. Fake, Engr. M. of W.	....
Missouri, Kansas & Texas......	3865	....	....	....	....	....	....	....	....
Missouri Pacific..............	7298	No	No	None	No	No	....	E. A. Hadley, Chief Engineer	....
Mobile & Ohio................	1403	No	No	None	No	....	....	B. A. Wood, Chf. Engr. M.W.& S.	Not in position to use forms.
Monongahela..................	111	....	....	....	....	....	....	....	....
Muskogee, Oklahoma & Gulf...	....	....	....	....	....	....	....	....	....
Nashville, Chattanooga & St. Louis..................	1231	No	No	None	No	No	....	H. McDonald, Chief Engineer	Use untreated white oak.

USE OF FORMS M. W. 301, 302, 303, 304—Continued.

Name of Road	Mileage	1 Are These Forms Now in Use on Your Road	2 Have You Ever Made Use of Them	3 If So to What Extent	4 Is It Your Intention to Place Them in Use on Your Road	5 Have You in Use on Your Road Any Forms Similar to These for Compiling Statistics of Cross Ties	6 If You Have Such Form Please Attach Copy	Reply Made by	Remarks
New York Central Lines.......	12161								
N. Y. C. Lines (East).......		No	No	None	No	Yes	Attd.	G. W. Vaughan, Engr. M. of W.	Attached forms now in use. See letter accompanying.
N. Y. C. Lines (W. of Buffalo)		No	No	None	No	....	Attd.	G. C. Cleveland, Chief Engineer	Attached forms now in use.
Pittsburgh & Lake Erie.....		No	No	None	No	....	....	J. A. Atwood, Chief Engineer	Does not think forms used his road any value to Committee.
Rutland....................		....	....	....	....	....	....	....	....
Toledo & Ohio Central......		No	No	None	No	No	....	J. A. Stocker, Chief Engineer	....
Michigan Central...........		No	No	None	....	No	....	G. H. Harris, Asst. Chief Engineer	Test sections.
Cincinnati Northern.........		No	No	None	Yes	No	....	W. D. Williams, Chief Engineer	....
Indiana Harbor Belt.........		No	No	None	No	No	....	Otto Gersbach, Engineer M. of W.	....
Clev., Cinn., Chicago & St. L.		No	No	None	No	....	Attd.	C. A. Paquette, Chief Engineer	Attached forms used.
Lake Erie & Western.........		No	No	None	No	No	....	J. K. Conner, Chief Engineer	....
New York, Chicago & St. L...	523	No	No	None	No	No	....	E. E. Hart, Chief Engineer	....
New York, New Haven & Hartford..................	2003	No	No	None	....	No	....	W. J. Backes, Chief Engineer	Considering use of forms.
New York, Ontario & Western.	568	No	No	....	....	....	....	W. C. Heidenthal, Engineer M. of W.	Just replied "not in use."
Norfolk & Southern...........	907	No	No	None	....	....	....	F. L. Nicholson, Chief Engineer	Forces too small to keep records.
Norfolk & Western............	2085	No	No	None	No	No	Attd.	J. E. Crawford, Chief Engineer	Attached form used. Do not use treated ties.
Northern Pacific.............	6727	No	No	None	No	No	....	A. M. Burt, C. E. L. Yager, E. M. of W.	Keep only number of ties.
Pennsylvania Lines West.......	4025								
Southwest System...........		No	No	None	No	Yes	Attd.	W. C. Cushing, Chief Engr. E. M. of W.	Attached forms used.
Northwest System..........		No	No	None	No	Yes	Attd.	R. Trimble, Chief Engr. M. of W.	Test section of 5 miles on each Supervisor's Subdivision. Record being kept of these.
St. Louis System...........		....	....	....	....	....	....	....	....

Pennsylvania	5388								
Pere Marquette	2247	No	No	None	No	No		Job Tuthill, Chief Engineer	
Peoria & Pekin Union	20	No	No	None	No	No		A. J. Wharf, Chief Engineer	Keeps book record.
Philadelphia & Reading	1608	No	No	None	No	No		S. T. Wagner, Chief Engineer	
Pittsburgh & West Virginia	63								
Pittsburg, Shawmut & Nor.	204	No	No	None	No	Yes	Attd.	H. S. Wilgus, Engineer M. of W.	Attached form in use.
Pittsburg & Shawmut	96								
Public Service	809	No	No	None	No	No		M. Schreiber, Chief Engineer	
Richmond, Fredericksburg & Potomac	124	No	No	None	No	No		S. B. Rice, Engineer M. of W.	
Richmond Terminal									
Rio Grande & Eagle Pass	28								
St. Joseph & Grand Island	258								
St. Louis, Brownsville & Mexico	528								
St. Louis-San Francisco	4769	No	No	None	No	No		V. K. Hendricks, Asst. Chief Engineer	Test sections have been put in.
St. Louis Southwestern	1685	No	No	None	See note			C. D. Purdon, Chief Engineer	Trying to get road to adopt A R E A forms.
St. Louis, Troy & Eastern	27								
San Antonio & Aransas Pass	724								
Southern New England	78								
Seaboard Air Line	3449	No	No	None	Cannot say	No		W. D. Faucette, Chief Engineer	
Southern Railway	7940								
Eastern Lines		No	No	None	No	No		B. Herman, Chf. Engr. M. of W.	
Western Lines		No	No	None	No	No		C. Dougherty, Chf. Engr. M. of W.	
Southern Pacific System	11943								
Southern Pacific Company		No	No	None	No	Not so elaborate	Attd.	J. Q. Barlow, Asst. Chief Engineer	Attached form used.
Sou. Pac. Lines in Tex. & La.		No	No	None	No	No		F. M. Lucore, Asst. Genl. Mgr.	Nothing similar, so can furnish no information.
Sou. Pac. Lines in Mexico									
Spokane International	163								
Spokane, Portland & Seattle	556								
Susquehanna & New York	103								
Temiskaming & Nor. Ontario	330	No	No	None	No	No		S. B. Clement, Chief Engineer	
Term. R. R. Assn. of St. L.	12	No	No	None	No	No		H. J. Pfeifer, Engineer M. of W.	Not desirable to keep record.

USE OF FORMS M. W. 301, 302, 303, 304—Continued.

Name of Road	Mileage	1 Are These Forms Now in Use on Your Road	2 Have You Ever Made Use of Them	3 If So, to What Extent	4 Is It Your Intention to Place Them in Use on Your Road	5 Have You in Use on Your Road Any Forms Similar to These for Compiling Statistics of Cross Ties	6 If You Have Such Form Please Attach Copy	Reply Made by	Remarks
Texas Midland	125								
Texas & Pacific	1944	No	No	None	No	No			
Toledo, St. Louis & Western	451	No	No	None	No	No		F. R. Ramsey, Chief Engineer	
Toledo & Western	81								
Toronto, Hamilton & Buffalo	101								
Toronto Terminals									
Twin City Rapid Transit Co.		No	No	None	No	No		G. L. Wilson, Engineer M. of W.	
Uintah	68								
Union Pacific System	7981								
Union Pacific		No	No	None	No		Attd.	R. L. Huntley, Chief Engineer	Attached copy form 3088. Present form not satisfactory.
Oregon Short Line	2229	No	No	None	No	No		C. Stradley, Chief Engineer	Reports on only treated ties removed.
Oregon-Wash. Ry. & Nav. Co.	2027								
United Rys. & Electric Co.									
United Traction Company		No	No	None	See note	See note		L. A. Mitchell, Superintendent	Will probably put forms in use in one or two years. Attached form in use.
Utah Light, Ry. & Power Co.	48								
Virginian	474	No	No	None				H. Fernstrom, Chief Engineer	Too much clerical work required.
Wabash	2510	No	No	None	No			A. O. Cunningham, Chief Engineer.	Benefit would not pay for keeping up.
Washington Terminal Co.	52	No	No	None	Possibly later			C. S. Heritage, Engineer	
Watauga & Yadkin River	31								
Waterloo, Cedar Falls & Nor.	135	No	No	None	In next few years	No		T. E. Rust, Chief Engineer	Force too small to follow up.
Western & Atlantic									
Western Maryland	773	No	No	None	No	No		M. C. Byers, Asst. to President	Do not use treated ties.
Wheeling & Lake Erie	459								
Winchester & Western		No	No	None	Yes	No		W. McC. Bond, General Manager	In course of construction.

Appendix C.

REPORT ON TRIALS OF SUBSTITUTE TIES.

H. S. Wilgus, Chairman, Sub-Committee.

Atchison, Topeka & Santa Fe Railway:

Universal.—(M. C. Blanchard, Engineer, Eastern District, October 24, 1917.) These are located in the Chicago Yard, between mile posts one and two, and in front of the depot at Florence, Kansas. Those at Chicago were placed in the eastbound main in March, 1911, and are 83 in number. They are still in the track and have not been disturbed since they were placed, with the exception of changing out the fiber insulation. Considerable corrosion has taken place, but not to the extent to render the tie unserviceable. Those at Florence are still in fair condition, their appearance being better than a year ago account of the large amount of oil which they are coated with, as result of the leak from tank cars passing over them. Some trouble is also encountered with the insulation at this point.

Baird.—There are only three of these ties, located in the yard at Newton, Kansas, but to date they have been giving very satisfactory service, little deterioration or corrosion having taken place. There is some play between the rail and the tie caused by wear between the two metal surfaces. There is also some side wear on the rail clips, and probably some trouble would be experienced in keeping the track in line were all of the ties of this make.

Carnegie.—The Carnegie steel ties in service at Chanute, Kansas, and Newton, Kansas, are in fair condition, but some trouble is being experienced with the rail clip and the bolt which holds it in place, both of these being too light, as is also the top flange of the "I" beam.

Baltimore & Ohio Railroad:

Boughton.—(Earl Stimson, Engineer Maintenance of Way, August 11, 1917.) In regard to the Boughton ties which were placed in the track at Akron, Ohio, in 1904, the status of these ties is the same as quoted in the 1917 Proceedings.

Metal Tie Company's Ties.—In regard to the Metal Tie Company's ties in track at Martinsburg, the status of these ties is the same as reported in the 1916 Proceedings, except that the blocking which was renewed in 1916 on account of being cut square (and not tapered) did not fit the casting of the tie, considerable difficulty being experienced in keeping tight. New blocks were therefore sawed out tapered so as to fit casting and installed May 16, 1917. Considerable difficulty has been experienced keeping these ties plumb, the tendency being for the top of the tie to lean against the traffic.

Carnegie.—The Carnegie ties which were under test at Marriottsville, Maryland, have been removed from the track and test closed.

Hardman.—Plan: Do not have. Description: A composition crosstie, made up of strips of wood bound together with seven strap iron bands ⅛x½ wide, being covered with a sort of asphaltum pitch material. A sample skeleton tie furnished by the manufacturers for inspection was made up of eighteen pieces or strips of wood, all 8 ft. long, the dimensions of which varies from ¼x1½ to 1⅝x3½. These strips of wood were made from various grades of green white oak, red oak, beech, etc.

The filler material is a heavy thick black substance, the covering on the sides and ends of the tie being about ¼-in. thick. The finished tie measures 6 in. x 7½ in. x 8 ft. long.

Main track or siding: These ties were installed in the eastbound freight track west of West Baltimore station, telegraph pole 3-31 to 3-35. The alinement at this point is on spiral of a 3 deg. 43 min. curve.

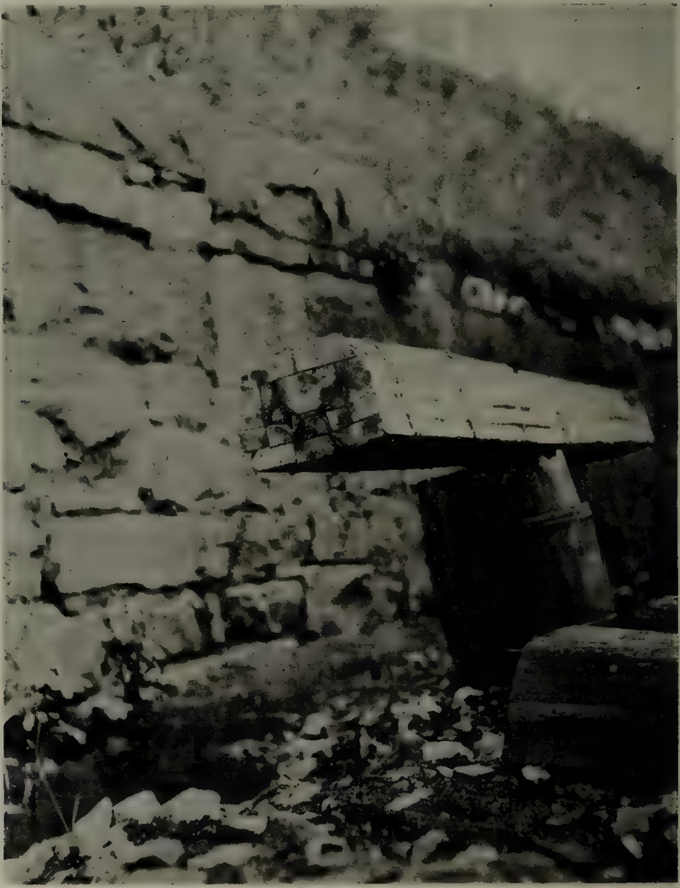


Fig. 1.—Hardman Tie.

Baltimore & Ohio Railroad, Baltimore, Md.

The ties were installed alternately with the wooden ties already in track, that is, a Hardman tie was put in at every other tie.

Weight of rail: The track at this point is laid with 100-lb. R. B. rail rolled by the Maryland Steel Company in 1914 and laid in 1915.

Character of ballast: Stone.

No. of ties per 33 ft. rail: 18.

Character of sub-grade: Clay.
Total number of ties laid: 29.
Date installed: May 29 and 30, 1917.
Weight of tie: 171 lb.
Cost: Donated by manufacturer.
Point of manufacture: Fall River, Mass.
Photograph: (See Fig. 1.)

Bessemer & Lake Erie Railroad:

Carnegie.—(H. T. Porter, Chief Engineer, December 8, 1917.) In line with your request for information for the Tie Committee covering the use of steel ties on the Bessemer & Lake Erie Railroad during the past year, I would advise that we have received no steel ties from the mills since our last report to the Committee. It is probable that no steel ties will be received from the mills until the extraordinary demand for steel, due to the war, has let up.

The only development of interest during the past year is that a fastening has been developed for use with 130-lb. P. S. section rail, prints of which are attached. We have laid some six or seven miles of main track using this fastening. (See Fig. 2.)

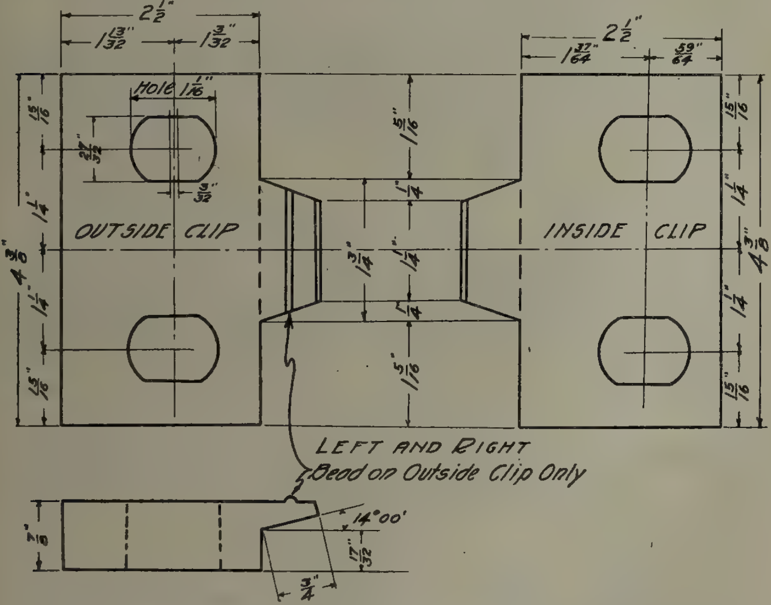


Fig. 2.—Two-Hole Center V-Wire Clips for 130-Lb. P. S. Rail.

Boston & Maine Railroad:

Carnegie.—No progress report.

Buffalo, Rochester & Pittsburgh Railway:

Carnegie.—No progress report.

Chicago & Alton Railroad:

Simplex.—No progress report received.
The Railway Tie Corporation.—No progress report received.

Cleveland, Cincinnati, Chicago & St. Louis Railway:

Carnegie.—(C. A. Paquette, Chief Engineer, August 11, 1917.) As previously reported by me, we have about a mile of Carnegie ties in our main track east of Greensburg, Ind. One of these ties was removed from the track about a week ago on account of failure, this failure occurring in the top flange under the rail. The flange was cracked on each side of the rail and this fracture extended through the web. The dirt and scale were thoroughly removed from the tie and it was weighed, and it was found to weigh 174½ lb. Our records indicate that the original weight of these ties was 179 lb. The loss in weight, therefore, was about 2½ lb. The corrosion on all of the ties in service seems to be about the same as on the one removed. This is the only tie thus far which has shown complete failure, but observations disclose that some of the ties still in the track are slightly surface-bent under the rail. These ties were put in the track during the winter of 1906.

Cornwall & Lebanon Railroad:

Snyder.—(A. D. Smith, Superintendent, August 14, 1917.) These ties were removed from the track several months ago. This was because of the fact that the concrete filling had become entirely disintegrated and the metal walls of the ties were crushing.

Denver & Salt Lake Railroad:

Shane.—No progress report.

Duluth & Iron Range Railroad:

Carnegie.—(W. A. Clark, Chief Engineer, August 17, 1917.) We have nothing further to report relative to the Carnegie Steel Ties, except that due to a serious derailment last May, we were obliged to remove 105 of these ties on Mile 79.

Duluth, Missabe & Northern Railway:

Carnegie.—(H. L. Dresser, Chief Engineer, August 15, 1917.) My letter of September 14, 1916, in regard to these ties, still holds good. They are still all in the track except the one which I mentioned last year, and are giving good service, and there is no evident reason why they should not be good for many years to come.

In reading over the statements from various railroad officials, as shown in the Proceedings of the Eighteenth Annual Convention of the American Railway Engineering Association in regard to the different types of steel and concrete ties which they have tried out, it has occurred to me that if many of them had not been to economical and had placed a sufficient number of ties to the rail length to take care of the load which they have to distribute in the ballast, results might have been different. I frequently notice in riding over roads where they have extremely heavy traffic, ties are not spaced as closely together as they might be. With the rolling stock which many of the railroads are using to-day, it is necessary to place the ties as near together as they can be and give sufficient room for properly tamping them. Otherwise, it is impossible to keep good surface on the track.

Elgin, Joliet & Eastern Railway:

Carnegie.—(A. Montzheimer, Chief Engineer, September 18, 1917.) This is an ideal tie for our purposes and so far has caused us no trouble whatever. It holds the track in good line and requires very little attention. The track seems to hold its surface remarkably well. The steel tie clips have not been tightened since they were installed, except the retightening which was necessary about two weeks after the ties were put in. The clip acts as an anti-creeper for the rail and there is no trouble on account of the steel running.

Bates.—These ties are still in good condition and apparently the same as when first installed. These ties have now been in service five years, having been installed in 1912. The steel truss connection between the two blocks of concrete which form the tie seem to give the track the same amount of elasticity which it would have with wooden ties, and I think this is a great advantage.

Erie Railroad Company:

Carnegie.—(R. S. Parsons, Assistant to President and Chief Engineer, October 1, 1917.) In reference to Carnegie switch ties this company has in use at Jamestown. We have experienced difficulty in the maintenance of these ties account of the clip fastenings. These have been adjusted and modified locally and the ties kept in service thus far. The wear in them has become so pronounced that we expect it will be necessary to remove the ties within another year.

Florida East Coast Railway:

Percival.—(E. Ben Carter, Chief Engineer, August 14, 1917.) I beg to advise that so far as I can observe, there has been no change in the condition of these ties since the report of our Mr. C. S. Coe, Engineer Maintenance of Way (who is now in France with the 17th Regiment of Railroad Engineers), under date of August 21, 1916, and addressed to Mr. L. C. Hartley, Chief Engineer of the Chicago & Eastern Illinois Railroad, then member of Sub-Committee No. 4, Committee on Ties, American Railway Engineering Association, previous and similar reports on these ties appearing in Association Reports, Vol. 14, page 754, and Vol. 15, page 752. And the report to Mr. Hartley was practically the same as that made to yourself by Mr. Coe under date of October 2, 1915.

In other words, the ties are giving entire satisfaction so far as wear is concerned, and have now been in our main track over 11 years.

Galveston, Harrisburg & San Antonio Railway:

Percival.—No progress report.

Huntingdon & Broad Top Mountain Railroad & Coal Company:

Stoneback.—(A. E. Yohn, Superintendent, November 17, 1917.) The Stoneback ties, the three ties which were placed in the track on April 1, 1915, and referred to in my letter of May 12, 1916, are still in the track and are in as good condition as they were on my last report. On July 13, 1916, 16 ties of this pattern were placed in our main track, near Long Siding, and are still in the track. The concrete on some of these ties cracked considerably after they were placed in the track, but they have not been removed and are apparently getting no worse.

Lake Champlain & Moriah Railroad:

CARNEGIE.—(M. Moore, Superintendent, August 9, 1917.) Relative to the Carnegie ties we have in use, I have nothing further to report, except that they are still in the track and giving good service.

Lake Erie & Western Railroad:

BUHRER.—(J. K. Conner, Chief Engineer, September 11, 1917.) There are seven of these ties still in our track, two of which will have to come out this season, five of the ties still being in good condition. These ties were wheel marked some time ago by derailments, which damaged them to a certain extent.

Lake Terminal Railroad:

CARNEGIE.—No progress report.

Long Island Railroad:

CARNEGIE.—No progress report.

Midvale Steel Company:

SNYDER.—(Radcliffe Furness, Assistant Superintendent, August 15, 1917.) We have given up the use of the Snyder steel ties for the reason that under our traffic they gave out under the rail where they are weakened by the holes punched for the holding device. The average life did not exceed that of a first-class white oak tie and they are considerably more expensive.

New York Central Railroad:

CARNEGIE.—(G. W. Kittredge, Chief Engineer, August 10, 1917.) The steel ties which we have heretofore reported upon have been put into use at places where engines clean their fires on existing tracks where wooden ties would be destroyed by being burned out. This is the only place where these ties are now in use, and for the purpose for which we are using them, they give comparatively good satisfaction.

New York Central Railroad (West of Buffalo):

BUHRER.—(G. C. Cleveland, Chief Engineer, August 10, 1917.) I have nothing further to report on this subject.

Northern Pacific Railway:

CARNEGIE—UNIVERSAL.—(L. Yager, Engineer Maintenance of Way, September 5, 1917.) We have not extended our use of Carnegie and Universal steel ties beyond that outlined in Chief Engineer Maintenance of Way Burt's letter of September 1, 1916. The purpose of these ties is to prevent destruction of wooden ties by engine cinders at coal docks and water stations. The use of these ties is, therefore, not comparable as a direct substitute for track ties. We have kept no data on the small installations we have that would be of any value on that phase of the subject in which your Sub-Committee is interested.

SOLID CONCRETE ROADBED CONSTRUCTION (three designs).—(L. Yager, Engineer Maintenance of Way, September 10, 1917.)

Plan: Type No. 1. Study plan of concrete roadbed, Office of Chief Engineer, February 15, 1914, Revised March 10, 1914.

Type No. 11. Reinforced concrete roadbed for experimental purposes, Office of Chief Engineer, April 11, 1914, Revised April 28, April 30, May 3 and June 15, 1914.

Type No. 111. Study plan of concrete roadbed, Office of Chief Engineer, May 28, 1912, Revised March 20, 1914.

Note: See Figs. 3, 4, 5 and 6.

Description: This will be evident from the plans and photographs.

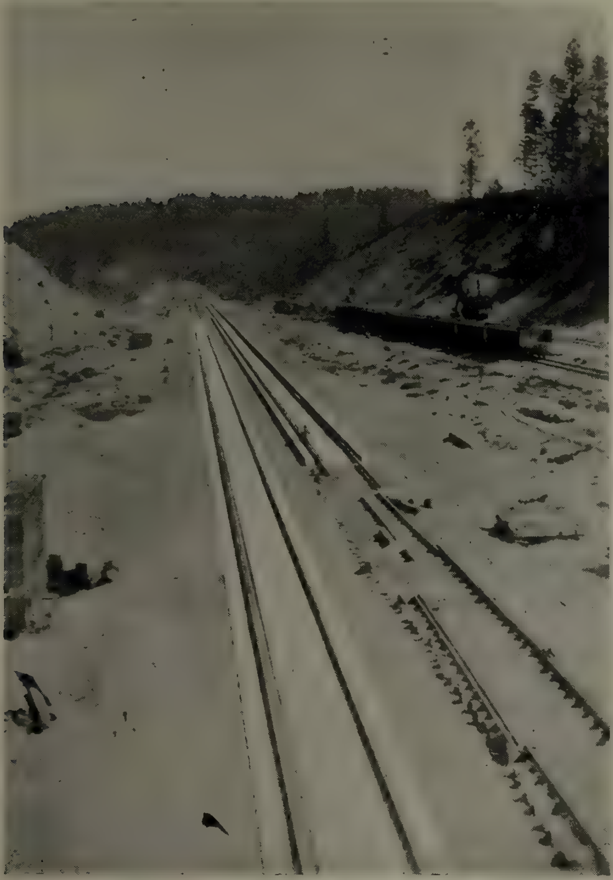


FIG. 3.—NORTHERN PACIFIC RAILWAY.

GENERAL VIEW LOOKING EAST, TYPE 3 IN FOREGROUND.

This experimental track was constructed in gravel cut at the time the line was originally constructed in 1914.

Main Track or Siding: On Main line in Mile 27 in first cut west of Nisqually River, Types Nos. 1 and 11 on Westbound Main, Type No. 111 on Eastbound Main. Portion of track profile attached.

Weight of Rail: Ninety-pound A. R. A. Type "B."

Date Installed: Constructed by company forces. Work began June 5, 1914, completed September 28, 1914.

Cost: The work was not handled in a manner which would make the cost of this particular piece of track any criterion of what the construction would cost if handled on a large scale.

How Constructed: The work was done at time of original construction of the new double-track line, Tacoma to Tenino. The concrete was cast in place.

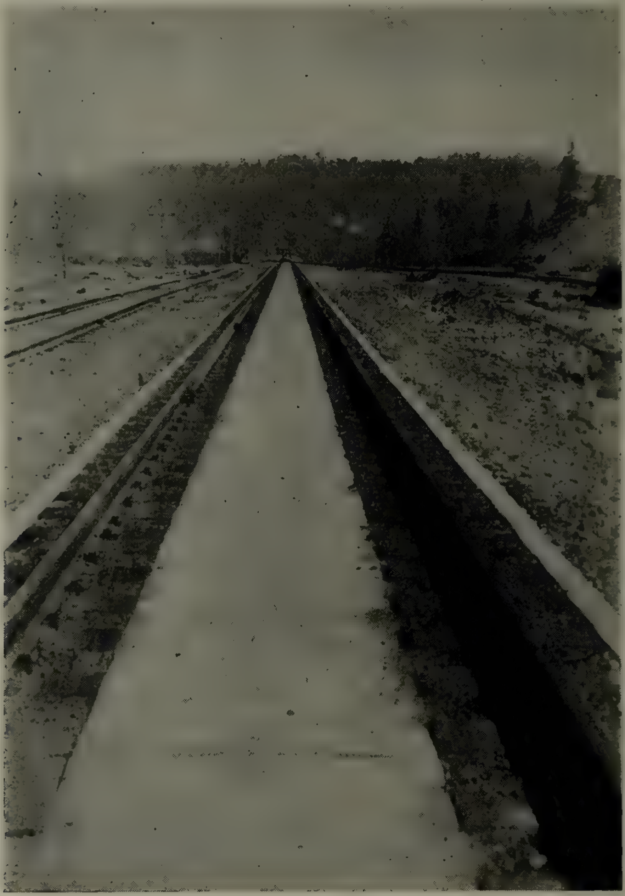


FIG. 4.—NORTHERN PACIFIC RAILWAY.

LOOKING EAST, TYPE NO. 1.

Where Used: One new double-track, low-grade line, Tacoma to Tenino, Mile 27, near Nisqually River crossing.

History to Date: Results as a whole to date have been satisfactory, although it is recognized that sufficient time has not elapsed to draw any definite conclusions of service, costs, etc. Some minor difficulties have arisen, such as the necessity of anchoring rails against creeping.

Additional Construction: No further construction of this kind is contemplated at present; but if we should decide to build more of it, we would make a number of changes in the design. The changes have not yet been worked out in plan form.

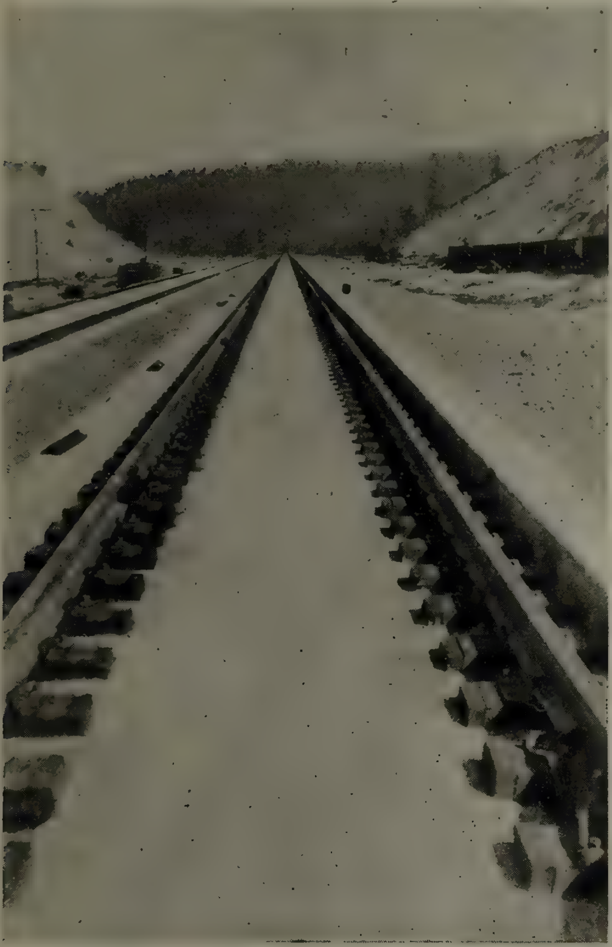


FIG. 5.—NORTHERN PACIFIC RAILWAY.

TYPE NO. 2, LOOKING EAST—TYPE NO. 3 ON LEFT.

Length: Type 1—594 ft. Type 11—594 ft. Type 111—810 ft.

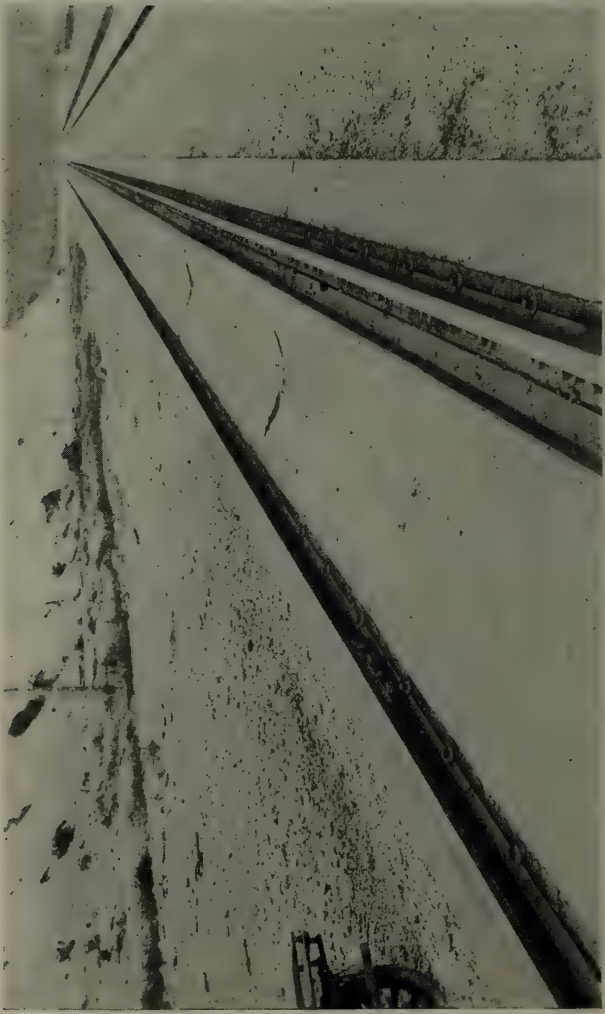


FIG. 6.—NORTHERN PACIFIC RAILWAY.

TYPE NO. 3, LOOKING EAST—TYPE NO. 2 ON RIGHT.

Pennsylvania Railroad:

Standard Steel Ties.—(W. G. Coughlin, Engineer Maintenance of Way, September 4, 1917.) Five hundred installed June, 1915, in eastbound freight track, Philadelphia Division, A. & S. Branch, east of Lenover, Pa. Some blocks have split. One hundred new oak blocks on hand for renewal.

Snyder Composite Tie.—Nine hundred and seventy installed in eastbound freight track, Philadelphia Division, A. & S. Branch, near Lenover, Pa., July, 1915, removed March, 1917, on account of disintegration of filling.

All removed from Johnstown Branch, April, 1916.

Eight hundred and twenty-one in westbound receiving track, Derry-Pittsburgh Division. Ties in fair condition. Signs of disintegration of filling.

Pennsylvania Steel Company Steel Ties.—Four (all) removed account of damage by derailed wheel March, 1917.

Leonard Concrete Ties.—Six in eastbound freight track, Philadelphia Division, A. & S. Branch, west of Atglen, Pa. Fair condition.

Carnegie Steel Ties.—One hundred and sixty-five removed February, 1917, account of web failure. Ten removed July, 1917, account of rivets becoming loose. Others in fair condition. Two thousand seven hundred and eight in service.

Carnegie Steel Switch Ties.—Sets installed in Pitcairn Yard September 11, 1911. One set No. 8 east end of ladder from 4, 5, 6 tracks No. 3 Repair Yard. Fifty-five ties in track; 2 clips gone; fair condition. Track recently thrown. One set No. 8 T. O. east end No. 1 track eastbound engine storage yard. Eight ties in track, underswitch; balance removed on account of damage due to derailment. One chair off; all others loose. One set No. 8 T. O. east end No. 2 track eastbound engine storage yard. Eight ties in track; balance removed account of damage, due to derailment. All chairs loose. One set No. 8 T. O. east end No. 12 track eastbound receiving yard. Forty-two ties in track; 10 removed on account of damage due to derailment; 15 ties in track damaged by derailment; 27 ties fair condition. One set No. 10 T. O. west end track No. 27 No. 1 repair yard. Sixty-four ties in track; 16 chairs loose; 9 clips loose; otherwise fair condition.

Mechling & Smith Steel Ties.—Eighty left in Wilkinsburg yard, Pittsburgh Division. Will last another year.

Shane Ties at Atglen.—Forty-five of original lot of Shane ties removed on account of failure; 45 Shane steel ties of heavier construction were installed. All of the fastenings of the ties removed were damaged to some extent. Ties in fair condition at present.

Pennsylvania Lines West of Pittsburgh, Northwest System:

Champion.—(R. Trimble, Chief Engineer Maintenance of Way, August 20, 1917.) Two hundred and three of these steel and concrete ties were placed in No. 1 westbound passenger track of the P. F. W. & C. Ry., just west of Emsworth, Pa., in November and December, 1913. They were removed from track on May 8, 9, 10, 1917, after a service of three years and five months. The primary cause of removal being the renewal of 100-lb. rail with 130-lb., the difference in the flange width of the rail requiring tie plate of a different dimension. After they were removed from the track they were found to be in such condition as not to warrant their being used again. In a large number of ties the steel was found to be cracked on one or both ends. While the condition found was not dangerous, it was feared that it might develop to a dangerous condition in the near future. In a large number of the ties the concrete was cracked and on account of lack of bond with the steel members, the concrete was slipping out at the end. A few of the tie plates were broken.

As regards corrosion, the ties were in very good shape, indeed, only a few of the ties showing any scale. The ties held up well, as practically every tie was as straight as when put in track, except for the flattening of the metal immediately under the rail.

It is our opinion that the tie was not well designed for the purpose of being filled with concrete, no provision having been made for shrinkage, and the possible separation of the steel from concrete.

This ends the experiment with the Champion ties.

Riegler Concrete Steel Ties.—Fifteen of these ties were placed in No. 1 track west of Emsworth, Pa., in May, 1908. In December, 1914, they were removed from that track and placed in No. 3 freight track. The reason for the change was that there had been some signal failures during the heavy wet snow in the spring of 1914, and in order to ascertain definitely whether these signal failures were attributable to these ties, or to other devices under test in that track, the Riegler concrete ties were removed and placed in No. 3 track. It was afterwards ascertained that the signal failures were due to other devices in this track. To date the ties have given about none and one-half years' service, six years of which was in a high-speed passenger and freight track, and three and one-half years in track used almost exclusively for freight purposes. In both tracks the service is very heavy. At the present time the condition of the ties is good. Two ties show some cracks in the concrete, which are, however, not considered of sufficient magnitude to effect the integrity of the tie. There is no apparent depreciation due to corrosion of the steel members. The contact between the concrete and the steel is as intimate as when the ties were first put in the track. No separate record has been kept of the cost of track surfacing and lining, but it is the opinion of those in charge that much less work is required for same than with a wooden tie. Our experience has demonstrated that these are good ties, answering all the requirements, the only objection being as to the cost. It is very probable that these ties would be found economical in tunnels or other places where the cost of maintenance of track is quite high, and where wooden ties require frequent renewal.

Pennsylvania Lines West of Pittsburgh, Southwest System:

Kimball.—On August 20, 1917, the last Kimball concrete tie, which was in service in No. 5 track at the west end of the westbound yard, Scully, Pa., was removed on account of being broken and unfit for use. The situation on the Southwest System of the Pennsylvania Lines West is, therefore, that at the present time, we have no concrete ties, either in main or side tracks.

Pittsburgh & Lake Erie Railroad:

Carnegie.—(J. A. Atwood, Chief Engineer, August 20, 1917.) Carnegie wedge tie at Pittsburgh removed and Carnegie steel tie at McKees Rocks removed 1917.

Maxey at Glassport removed.

Atwood at McKees Rocks is still in service and in good condition.

Riverside-Rialto & Pacific Railroad:

Wolf Concrete Tie.—(Following information obtained in part through the courtesy of W. H. Whalen, Superintendent, Southern Pacific, and in part from the Engineering News, March 15, 1917. The ex-

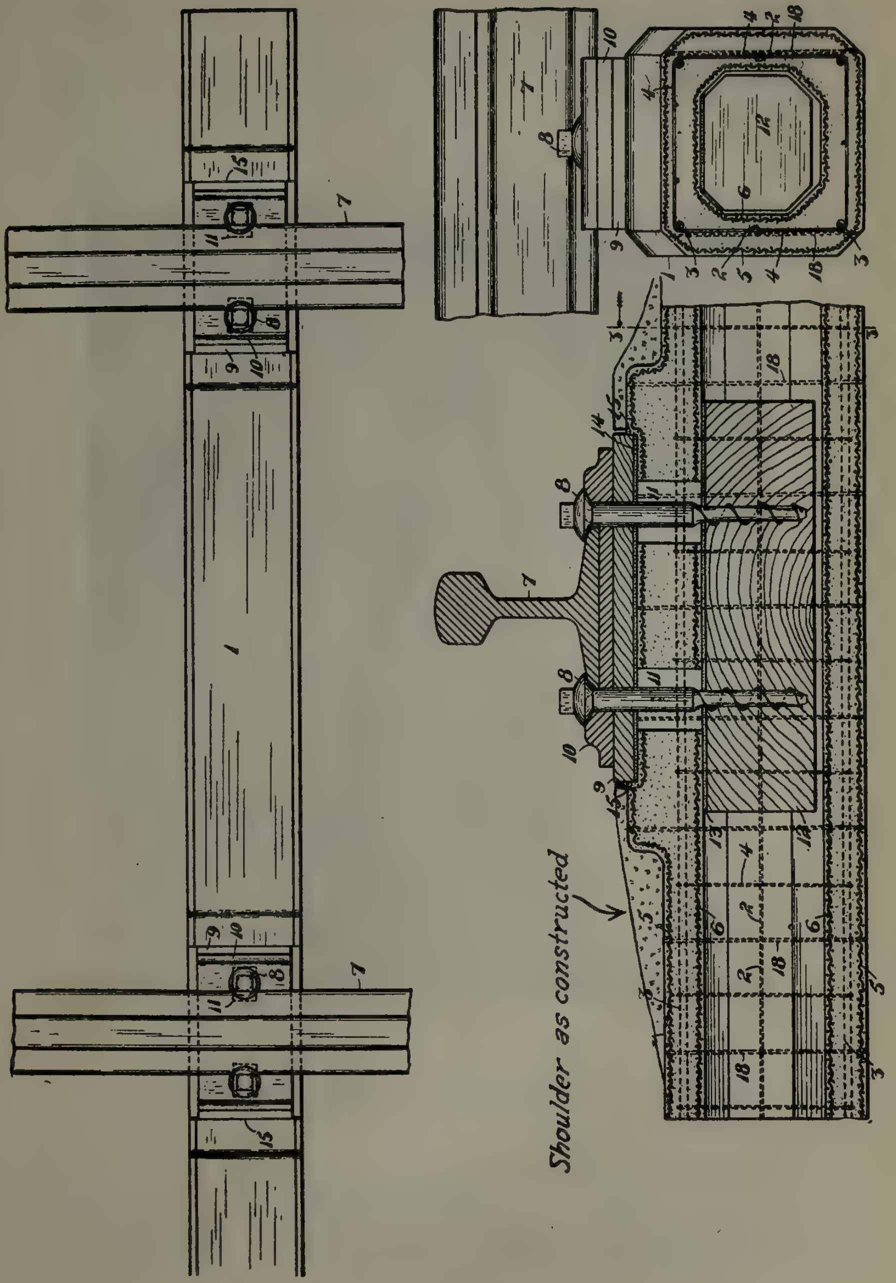


FIG. 7.—WOLF CONCRETE TIE.

periment is conducted under the direction of W. H. Bohon, General Manager of the R. R. & P. R. R.):

Plan: As per attached (see Fig. 7).

Description: Made with concrete, wire netting and rods with wood cushion block under tie.

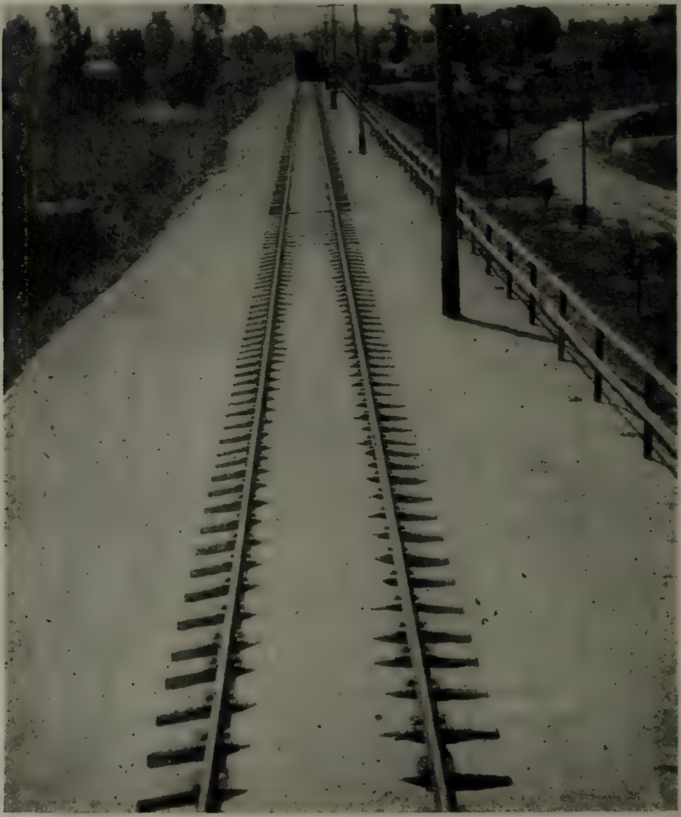


FIG. 8.—WOLF CONCRETE TIE.

RIVERSIDE, RIALTO & PACIFIC RAILROAD, RIVERSIDE, CAL.

Main track or siding: Main track. Weight of rail: 60-lb. Character of ballast: Gravel. Total number of ties per 33-ft. rail: Not given. Character of sub-grade: Clay. Total number of ties laid: 60. Date installed: October, 1913. Weight of tie: Not given. Cost: Not given. Point of manufacture: Not given. Photograph: (See Fig. 8.)

Southern Pacific Lines:

Indestructible Concrete Ties.—(I. A. Cottingham, Special Engineer, August 13, 1917.) Description: Cement, sand, gravel and steel. Main track or siding: Main line at lead switch. Weight of rail: 65-lb. Character of sub-grade: Cinders. Number of ties per 30-ft. rail: 16 ties. Total number of ties laid: 23. Date installed: May 5, 1916. Weight of tie: 660 lb. Cost: Approximately $1.80 per tie. Point of manufacture: Some at Eagle Pass and at Dallas, Tex. Do not understand that they are manufactured on a large scale, but just made for test purposes. List showing where used, if at more than one point: Know of no other place with the exception of Eagle Pass. Photograph: Attached. (See Fig. 9.)

Union Railroad:

No progress report received.

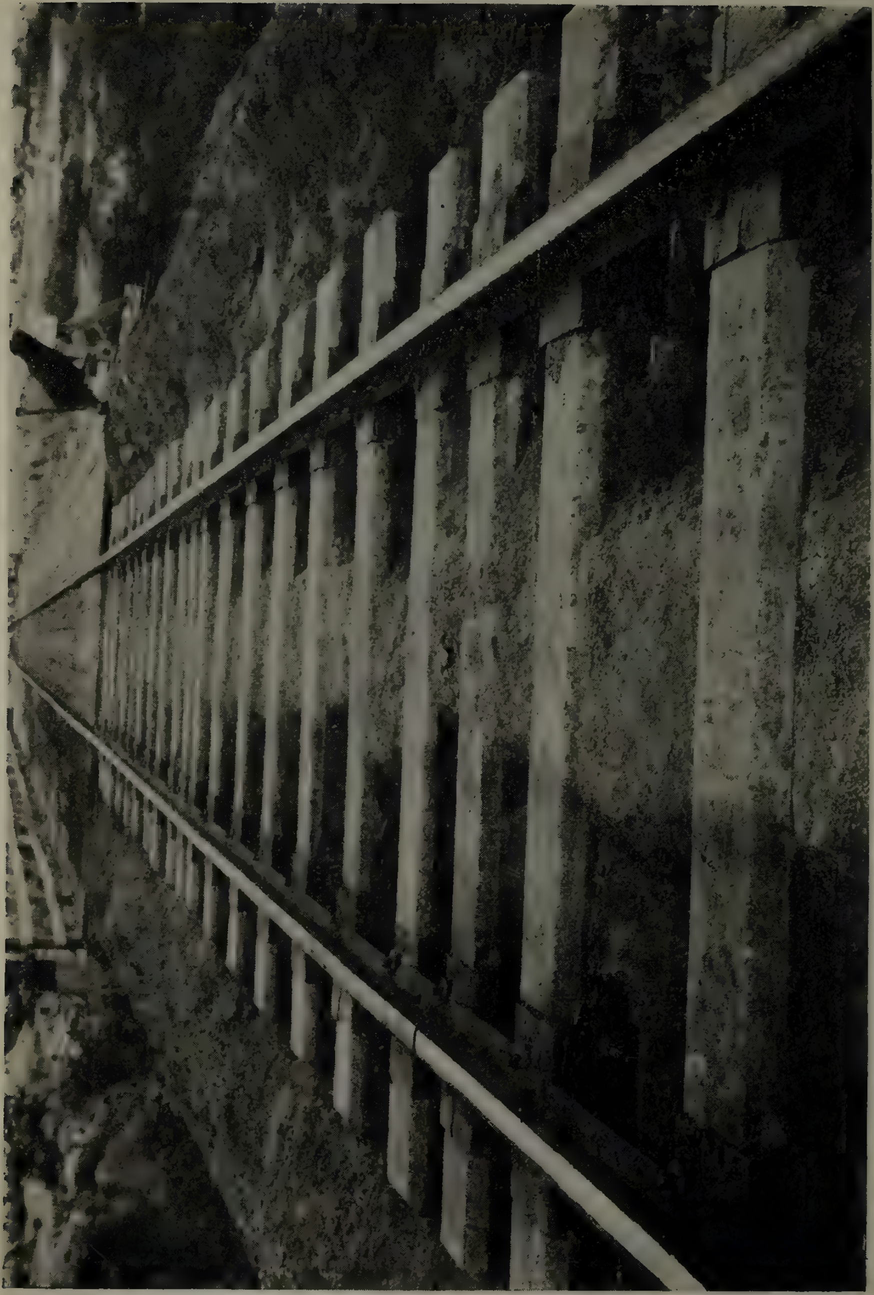


Fig. 9.—Indestructible Concrete Tie, Southern Pacific Co.

REPORT OF COMMITTEE I—ON ROADWAY.

W. M. Dawley, *Chairman;*
J. R. W. Ambrose,
H. E. Astley,
C. W. Brown,
S. P. Brown,
B. M. Cheney,
C. W. Cochran,
W. C. Curd,
Paul Didier,
S. B. Fisher,
W. C. Kegler,
F. Ringer,
J. A. Spielmann, *Vice-Chairman;*
H. W. McLeod,
C. M. McVay,
F. M. Patterson,
W. H. Petersen,
P. Petri,
W. F. Purdy,
R. A. Rutledge,
W. H. Sellew,
J. M. Sills,
G. R. Talcott,
W. P. Wiltsee,

Committee.

To the American Railway Engineering Association:

Your Committee on Roadway herewith presents its annual report for the year 1917.

The following subjects were assigned by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.
2. Subsidence Under Embankment.—Methods of determining extent, character and effect.
3. Shrinkage of Embankments.—Select a number of specific instances reciting all the conditions, such as locality, weather, foundation, etc., to be used as a guide in estimating shrinkage.
4. Report on prevention and cure of water pockets in roadbed.
5. Continue the study of unit pressures allowable on roadbeds of different materials, co-operating with Special Committee on Stresses in Railroad Track.
6. Consider and report on the best method for draining roadway through stations and yards.

Circumstances beyond the control of your Committee have prevented it from giving to the above subjects, other than No. 6, the full consideration necessary for making a satisfactory report thereon; but one meeting of the Committee as a whole in Chicago and one Sub-Committee meeting in New York were held during the year.

Some progress has been made in the consideration of subjects Nos. 1 to 5 and your Committee would ask that they be reassigned for consideration and report next year.

(6) REPORT ON THE BEST METHOD FOR DRAINING ROADWAY THROUGH STATIONS AND YARDS.

SUB-COMMITTEE

W. P. WILTSEE, *Chairman;* C. W. BROWN,
H. E. ASTLEY, H. W. MCLEOD,
J. M. SILLS.

Through the office of the Secretary the following letter was sent to representatives of about fifty of the larger railroads in the Association:

"One of the subjects assigned the Roadway Committee of the American Railway Engineering Association is "Consider and report on the best method for draining roadway through stations and yards.' For the benefit of the Sub-Committee handling this matter, will you please furnish them any information regarding this subject you can?

"(1) What is the practice on your railroad for handling drainage of this kind?

"(2) Have you ever had any special cases for which you provided a remedy? If so, please furnish full information regarding conditions and remedy.

"In furnishing this information, please give full details as to size of yards, number of tracks, grades, kind of material roadbed is composed of, kind and depth of ballast, etc.

"Please mail your replies direct to the Chairman of the Sub-Committee, Mr. W. P. Wiltsee, Assistant Engineer, Norfolk & Western Railway Company, Roanoke, Va."

About twenty replies to this letter were received, a short synopsis of which follows:

Seaboard Air Line Railway Company.

In the larger freight yards, use corrugated iron pipe under track, six or eight inches below subgrade, connecting between tracks to catch basins. At stations having concrete platforms and tracks in pairs between platforms, drainage is carried to an open ditch between tracks, thence through drain pipes under track to a suitable outlet. In special cases through yards, have built slight humps in yard tracks to direct the flow of water to small catch basins draining into cast iron drains. Use cinder ballast in yards.

Grand Trunk Railway System.

Have made no special provisions for draining roadway through stations and yards, except usually maintaining main tracks at a slightly higher level to form a water shed, and draining through open drains around the stations and yard tracks. When impracticable to drain around stations and yard tracks, covered drains are used.

Illinois Central Railroad.

Each case considered a separate proposition. In case of stations, have laid tile between tracks and the curbing of the platform, but do not recommend this practice. Best results have been obtained by cutting out the track and putting a deep bed of good ballast under it. In yards have obtained best results from installing a system of catch basins and lateral drains.

Philadelphia & Reading Railway.

For station grounds provide catch basins and pipe drains.

For yard tracks use 18 inches of cinder.

Wherever possible, provide open ditches to carry off the water, and where necessary, use pipe drains with inlets.

New York Central Railroad, West of Buffalo.

Place tracks adjacent to main lines about two inches below them, each succeeding track being stepped down to suit the normal trend of drainage. This method applies more particularly to small yards. In larger yards, where necessary, provide a number of transverse culverts, with frequent inlets. Use a large quantity of porous sub-ballast—in some cases two or three feet of cinders or slag.

Bangor & Aroostook Railroad.

Usually use wooden boxes about 10 in. by 10 in. section, with top flush with top of tie, for draining inside the yard; drainage outside of yard cared for by culverts. Use 12 inches of gravel ballast.

Pennsylvania Railroad.

Use porous terra cotta tile or Gallion cast iron drain between tracks. Where subsoil is of such a nature that such drains are quickly filled with silt, dig a trench about three feet between tracks and fill it with large stone. In special cases have used three-foot square wooden boxes between tracks. For drainage at station platforms, follow as a general plan the placing of terra cotta drain pipe not less than 12 inches in diameter laid on the line of the standard ditch under the station platform, with 6-inch drain pipes leading to it from a creosoted wooden drain pipe between tracks, three to four feet below base of rail. Use deep sub-ballast of cinder.

Mobile & Ohio Railroad.

Surface drainage taken care of by culverts. Have never had occasion to provide special drainage in yards, most of which are constructed of cinders and drain readily. Take care of surface water by necessary ditches and sewer system. Where necessary, use sub-surface tile drains of bell end vitrified pipe, about four feet under subgrade, on at least 0.3 per cent., filling ditch with porous material. Keep ballast between tracks three inches below ties. Use cinder ballast.

St. Louis Southwestern Railway.

Take care of surface water by large drains or ditches and cross tracks by wooden box culverts.

Atlantic Coast Line Railroad.

Take care of drainage for yards and stations by surface drain between the ties, or by small pipes placed under the ties. In a few instances have placed terra cotta pipe for leading water to favorable points of discharge. Soil forming the roadway in most all cases containing a large amount of sand.

Duluth, South Shore & Atlantic Railway.

Usually lay sewer tile of suitable diameter, with socket joints, cemented, connecting with catch basins between tracks. These catch basins are covered with heavy wire netting; from them drains lead to trunk line sewers. In some cases cross-drains of farm tile are laid under sidings and driveways to connections with above described drains.

Chicago, St. Paul, Minneapolis & Omaha Railroad.

Use drain tile covered with straw, and filling up remainder of trench with coarse cinders, constructed between tracks.

Pennsylvania Lines West.

Where necessary for draining through yards, construct trunk sewers parallel with the tracks, with lateral drains from 50 ft. to 100 ft. apart, as conditions require. Catch basins provided at each lateral connection with trunk sewers and between tracks on the laterals. Grades on sewers not less than 0.3 per cent. At station platforms, have frequently improved drainage by laying vitrified tile sewer pipe between tracks within the limits of the platform, with catch basins at frequent intervals.

Cleveland, Cincinnati, Chicago & St. Louis Railway.

Use a system of sewers with appurtenances, catch basins, etc. Use subdrains of title, laid a sufficient depth below subgrade to be unaffected by frost or movement of track, and cover with cinders.

Elgin, Joliet & Eastern Railway.

Where sub-drainage is necessary, use porous drain tile, back-filled with cinders, gravel or other porous materials. Generally provide drainage through ballast to subgrade.

Missouri, Kansas & Texas Railway.

In some cases use storm sewers, with inlets properly located to carry off surface water. Where necessary, install sub-drains.

Toronto, Hamilton & Buffalo Railway.

Use open ditches around the yard, with cross-drains of 12-in. tile 250 ft. apart, and with catch basins between tracks.

St. Louis-San Francisco Railway.

In many cases, use drainage system of vitrified pipe, from which laterals extend; also use catch basins between tracks. Use open ditches wherever practicable. Use slightly different elevations for various yard tracks so as to make a natural water shed of the yard.

New York, New Haven & Hartford.

Use cross-drains with frequent catch basins in larger yards, with special consideration for the best drainage along ladder tracks. At station platforms, have had good results with open ditches, under wooden platforms or between tracks. Side drains with a good supply of coarse material around joints have given excellent results.

Missouri Pacific Railroad.

Locate main sewers along lines of natural drainage, running laterals along or under the tracks, with inlets between tracks, and especially in the vicinity of switches.

CONCLUSIONS.

After consideration and discussion of the above replies the following conclusions were drafted and are submitted for your approval:

1. The drainage of roadway through stations and yards should be treated in accordance with local conditions.

2. Surface water should be carried off roadbed into drains as quickly as possible.

3. Items influencing mode of procedure are: Soil condition, contour of adjacent grounds, grade of tracks, number of tracks, amount of rainfall; etc.

4. Surface water should be taken care of first by open ditches as much as possible, where they will not interfere with the work of employes or the safety of passengers.

5. Where the subgrade is of such a nature that it will absorb water and not retain it, a sub-ballast of engine cinders should be used, the surface of which should not be allowed to become foul, but kept open so that water will penetrate the subgrade through the cinder. Where the subgrade will hold water, special effort should be made to carry it away from the subgrade by means of drains.

6. Tracks in yards should be so constructed where practicable that tracks adjacent to main lines will be about two inches below them and each succeeding track stepped down to suit the normal trend of drainage, thus providing drainage laterally as well as longitudinally.

7. Cross-drains of cast iron pipe, with catch basins between tracks, should be placed where necessary.

8. If the subsoil is of such a nature that it retains water and becomes saturated therewith, place bell and vitrified drain pipe with open joints between tracks and about four feet below base of rail, using special care to put them below frost and deep enough to get below the movement of the soil; these pipes running into cross-drains leading to natural drainage.

9. If subsoil is silty or of such consistency as to quickly fill up the pipe, a wide ditch should be dug, preferably between tracks, and filled with large stone, having pipes leading off from it to the natural drainage.

10. At station platforms a subdrain of iron pipe, with catch basins at frequent intervals, should be laid alongside the curbing, or bell end vitrified pipe may be laid between tracks a sufficient depth to be below frost and movement of the soil. These drains to be connected by means of side drains to natural ditches, or in cuts to bell end vitrified subdrain laid in the ditch line.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

As before stated, your Committee recommends that Subjects 1 to 5, inclusive, assigned for consideration this year be reassigned for next year's work.

Respectfully submitted,

The Committee on Roadway.

REPORT OF COMMITTEE IV—ON RAIL.

John D. Isaacs, *Chairman;*
E. E. Adams,
E. B. Ashby,
J. A. Atwood,
A. S. Baldwin,
W. C. Barnes,
Chas. S. Churchill,
W. C. Cushing,
G. M. Davidson,
Dr. P. H. Dudley,
J. M. R. Fairbairn,
L. C. Fritch,
A. W. Gibbs,
Howard G. Kelley,
R. Montfort, *Vice-Chairman;*
C. F. Loweth,
H. B. MacFarland,
C. A. Morse,
A. W. Newton,
J. R. Onderdonk,
G. J. Ray,
H. R. Safford,
J. P. Snow,
F. S. Stevens,
Earl Stimson,
R. Trimble,
M. H. Wickhorst,

Committee.

To the American Railway Engineering Association:

Your Committee on Rail respectfully submits herewith its report to the Nineteenth Annual Convention.

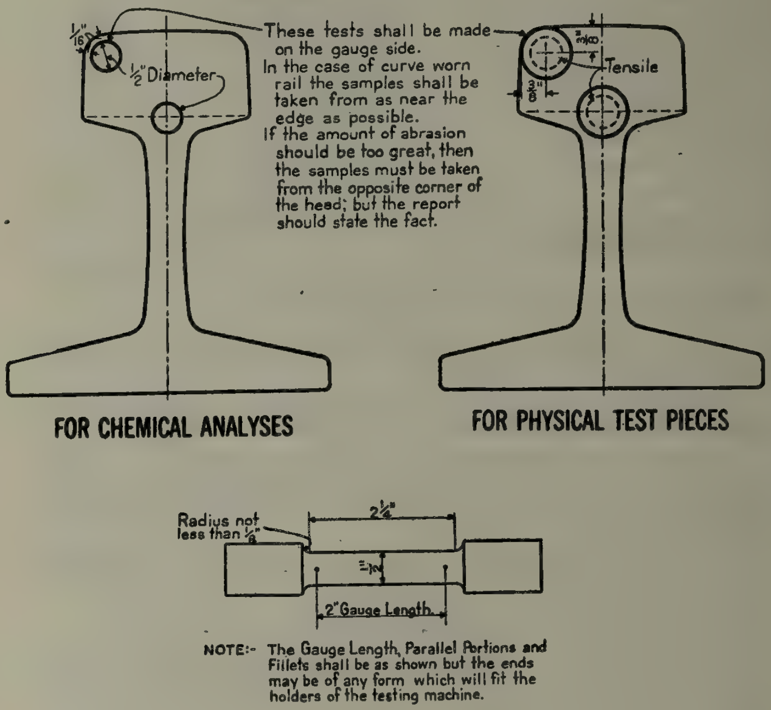
The subjects assigned the Committee for 1917 by the Board of Direction for investigation and report were as follows:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, giving special attention to the rail designs recently adopted and to the specifications for carbon steel rails and joint bars.
2. Report on rail failures and present statistics and conclusions as to causes and submit suggestions for improvement.
3. Continue special investigation of rails.
4. Report on track bolts and nutlocks.
5. (a) Report on details of manufacture and mill practice as they affect rail quality.
   (b) Continue research on the possibility of various improvements in methods of manufacture of steel rails.
6. Make critical study of joint bars from the standpoint of design and material, together with laboratory tests, including strain-gage measurements after having established a uniform method for comparative testing.
7. Report on relative value of material for joint bars, quenched only versus quenched and tempered, and whether it is most advantageous to quench in oil or water, submitting specifications therefor.
8. Report on rational relation between intensity of pressure due to wheel loads and resistance of rail steel to crushing and deformation.
9. Continue investigation and development of methods of inspection.
10. Report on Federal and State Commission rulings.

Meetings were held in 1917 as follows: Pittsburgh, April 24, with 12 present; Atlantic City, June 25, with 18 present; Chicago, November 22, with 14 present.

(1) REVISION OF MANUAL.

The Manual for 1915, page 88, shows three locations of borings for chemical analyses of rails, one in an upper corner of the head, one in the interior of the head near the web and the third in a flange. Experience and special tests have shown that the samples from the corner of the head and from the flange have about the same chemical composition and for general purposes the flange sample may be omitted.



These tests shall be made on the gauge side. In the case of curve worn rail the samples shall be taken from as near the edge as possible. If the amount of abrasion should be too great, then the samples must be taken from the opposite corner of the head; but the report should state the fact.

FOR CHEMICAL ANALYSES

FOR PHYSICAL TEST PIECES

NOTE:- The Gauge Length, Parallel Portions and Fillets shall be as shown but the ends may be of any form which will fit the holders of the testing machine.

Fig. 1.—Locations of Samples from Rails for Chemical Analyses and Physical Tests.

The same page of the Manual also shows a drawing for the tensile test specimen of one-half inch diameter and two inches gage length, with threaded ends. This followed the standard of the American Society for Testing Materials, who have modified their standard by omitting the threaded ends and allowing the ends to be of any form which will fit the holders of the testing machine. Our drawing should also be modified in the same manner to accord with current practice in testing laboratories. A drawing is given herewith as Fig. 1, showing these changes and the Rail Committee recommends this drawing be substituted for the one on page 88 of the 1915 Manual.

The 1915 Manual contains "Specifications for High-Carbon Steel Joint Bars" (page 89) and "Specifications for Heat-Treated, Oil-Quenched Steel Joint Bars" (page 91). At the convention of the Association in March, 1916, the Committee submitted "Specifications for Quenched Carbon and Quenched Alloy Steel Joint Bars," to be held over for one year (Proc. 1916, pages 488 and 920). At the 1917 convention, some changes were submitted and it was again recommended that the specifications be held over for another year (Proc. 1917, pages 908 and 1457). The Committee now presents these specifications as modified last year as Appendix A, with the recommendation that they be adopted and supersede in the Manual the "Specifications for Heat-Treated, Oil-Quenched, Steel Joint Bars."

As explained below in the discussion of Subject 4, the Committee recommends new track bolt specifications to take the place of those now in the Manual.

(2) RAIL FAILURE STATISTICS.

The statistics covering rail failures for the period ending October 31, 1916, were issued in Bulletin 199 for September, 1917. (See Appendix D.) The average failures per 100 track miles of the rollings for the several years, including both Bessemer and open-hearth rails, are given herewith. This summary includes statistics from reports for 1913, 1914, 1915 and 1916:

Year	Years Service				
Rolled	1	2	3	4	5
1908	....	....	.....	.....	398.1
1909	....	....	.....	224.1	277.8
1910	....	....	124.0	152.7	198.5
1911	....	77.0	104.4	133.3	176.3
1912	28.9	32.1	49.3	78.9	.....
1913	12.5	25.8	44.8	.....	.....
1914	8.2	19.8	.....	.....	.....
1915	8.9	....	.....	.....	.....

It will be noted that the four years' rollings from 1908 to 1911, inclusive, show successively decreased numbers of failures compared on a basis of five years' service and the later rollings compared on a shorter period of service also show reductions. The improvement may probably be ascribed mostly to three things, namely, the gradual replacement of Bessemer by open-hearth rails, the adoption of heavier rails with stronger bases, and the improvement of the metal used for rails.

(3) SPECIAL INVESTIGATIONS.

During the year special reports have been presented by the Rail Committee as follows:

No. 64—Mill Inspections of Rail in 1915 and 1916, by M. H. Wickhorst. (Bulletin 199.) (See Appendix C.)

No. 65—Rail Failure Statistics for 1916, by M. H. Wickhorst. (Bulletin 199.) (See Appendix D.)

No. 66—Influence of Gage Length on Elongation in Drop Test of Rails, by M. H. Wickhorst. (Bulletin 199.) (See Appendix E.)

No. 67—Tests of Manganese Steel Rails, by M. H. Wickhorst. (Bulletin 199.) (See Appendix F.)

No. 68—Inhibited or Delayed Transformations in Rail Heads, by Dr. P. H. Dudley. (Bulletin 203.) (See Appendix G.)

No. 69—Intensity of Pressure on Rails, by a Sub-Committee, J. R. Onderdonk, chairman. (Bulletin 203.) (See Appendix H.)

The paper on "Mill Inspections of Rail in 1915 and 1916" is discussed below under subject "Mill Practice."

The paper on "Influence of Gage Length on Elongation in Drop Test of Rails" gives a comparison of the per cent. of elongation when measured over six inches and over one inch. An elongation of six per cent. in six inches is equivalent to about 7.3 per cent. in the "maximum" inch.

The paper on "Tests of Manganese Steel Rails" is a compilation of reports of tests of manganese steel rails furnished by a number of railroads represented on our Rail Committee. According to these results, manganese steel rails abraded much less on sharp curves than carbon steel rails, but they became somewhat more distorted by spreading and drooping of the head.

The paper on "Inhibited or Delayed Transformations in Rail Heads" discusses the cause of internal fissures in rails as worked out by Dr. Dudley on the New York Central Lines.

The paper on "Intensity of Pressure on Rails" is discussed below as Subject 8.

(4) TRACK BOLTS AND NUTLOCKS.

At the convention of the Association in March, 1916, the Rail Committee submitted "Specifications for Quenched Carbon and Quenched Alloy Steel Track Bolts with Nuts," and "Specifications for Medium Carbon Steel Track Bolts with Nuts," as shown on pages 490-494, inclusive, of the 1916 Proceedings. The action of the convention was that these specifications be "held under consideration during the coming year with a view to final action next year." (See page 920 of the 1916 Proceedings.) No action was taken on this matter at the 1917 convention.

The Committee now recommends that the specifications submitted in 1916, with some changes, be adopted by the Association for insertion in the Manual in place of the "Specifications for Track Bolts" appearing on pages 123, 124 and 125 of the 1915 edition. The specifications now recommended are given as Appendix B and the changes from those submitted in 1916 consist of additions as follows:

Section 4—Both specifications.

After the first sentence there has been added, "It shall be homogeneous and when broken in tension, shall show a uniformly silky fracture."

Section 6—Both specifications.

At the end of the first sentence, after the word "material," there has been added, "and any other elements used to obtain the specified physical properties."

Section 14—For Quenched Bolts.

Section 13—For Medium Carbon Bolts.

After "threads" there has been inserted, "be well oiled to prevent rust, etc."

(5) MILL PRACTICE.

Information was gathered from the members of the Rail Committee as to the results of their inspections of rail at the mills which were given in the paper on "Mill Inspections of Rail in 1915 and 1916." This paper gave the general results of the mill inspections of rail manufactured in 1915 and 1916 for some of the railroads and also gives some discussion of the specifications on which the rails were bought. According to these results the average top discard from the ingot, of all rails, was 17.9 per cent.; the average elongation in the drop test was 14.5 per cent.; and the rejections were 6.4 per cent. Of all rejections, 42 per cent. were A rails.

(6) Study of joint bars from standpoint of design and material.

(7) Relative value of various heat treatments.

Tests are being made and the Committee reports progress on these subjects.

(8) INTENSITY OF PRESSURE AND RAIL RESISTANCE.

Extensive tests were made on the reciprocating wheel load machine at Sparrows Point, Md., dealing with the crushing effect on rail metal of various wheel loads, the report of which is issued as Report 69, Appendix H, in this Bulletin. Small tapered holes were drilled through from side to side of the head of test rails at various distances below the top of the head and accurately fitted with tapered pins. Any flowage of the metal under rolling wheel loads would cause a flattening of the holes and its amount could be measured by the distance the pins lacked of going into their original position.

Dr. P. H. Dudley has made some extensive measurements on rails in track, of the areas of contact and the distribution of the intensity of the pressure within the area of contact, the results of which are also given in the report.

For the present, the only conclusions that can be drawn from the tests which have been made are but indications, as follows:

Laboratory Tests:

1. That for this section and composition of rail, initial loads of 30,000 lbs. or more per wheel of cast iron and chilled tread, of 33 inches in diameter, were too great for the transverse holes, and produced flow or closure at least ⅜-inch below the bearing surface.

2. That loads of 25,000 lbs. produced but slight flow or closure in the three uppermost transverse holes, and this extending not more than ¼-inch in depth.

3. That preliminary light loads, by cold-rolling the surface, may adapt the material to subsequent heavier loads.

Field Tests:

4. The diagrams of the plotted tables show that the stresses in the metals are locally less severe than we had expected to find in the surfaces of the pressure zone contacts of the wheel tread and the rail head.

5. It is important, as the theory and evidence show that the metal of the circumjacent layer of each pressure zone of contact for the wheel tread, also that of the rail head, is in position not only to utilize the elasticity of the metal to help carry a given load, but to increase in area within the elastic limits of the metals nearly in proportion to the loads applied.

6. The action of the rolling wheels on the rail heads is a gradually applied load from zero to the maximum, then reducing again to zero, both for a unit length in the wheel tread or rail head, and is not a suddenly applied load, even for a mile-a-minute or faster trains.

7. The round type of area of contact shows the greatest average unit intensity of pressure.

8. The longitudinal oval, or the transverse oval type indicates the lowest average unit intensity of pressure.

9. The longitudinal elliptical or transverse elliptical, in which the major axis is two or more times the width of the minor axis, indicates also a favorable average unit intensity of pressure.

10. The transverse oval or elliptical under steel or cast-iron wheels is more favorable for the rail head than the round.

11. The reciprocal relations of the loads carried on the metal of the wheel treads to the metal of the rail heads should be studied from the voluminous service tests now available.

(9) METHODS OF INSPECTION.

Last year a paper was presented on "Rail Tests, Quick Bend Method," which gave the results of tests of rails by the Pennsylvania Railroad by means of an hydraulic bender. It is thought that inspection of rails by the hydraulic bender could be carried on much quicker than by the drop test. The Pennsylvania Railroad is testing rails by this means while carrying on the regular drop tests in the inspection of them, and it is hoped that a full comparison of the two methods will be obtained.

(10) COMMISSION RULINGS.

The Committee has been gathering information and reports progress on this subject.

RECOMMENDATIONS.

Your Committee submits the following recommendations for the approval of the Association:

1. That the locations for the physical test specimens and for chemical samples from rails as submitted with this report, be adopted by the Association to replace the diagrams shown on page 88 of the 1915 Manual.
2. That the "Specifications for Quenched Carbon and Quenched Alloy Steel Joint Bars," submitted with this report, be adopted by the Association and be substituted for the "Specifications for Heat-Treated, Oil-Quenched, Steel Joint Bars," on pages 91 to 93 of the 1915 Manual.
3. That the specifications for "Quenched Carbon and Quenched Alloy Steel Track Bolts with Nuts" and the "Specifications for Medium Carbon Steel Track Bolts with Nuts," submitted with this report, be adopted by the Association and be substituted for the "Specifications for Track Bolts," on pages 123 to 125 of the 1915 Manual.

RECOMMENDATIONS FOR FUTURE WORK.

The Committee recommends that the same topics be reassigned for 1918 as were given the Committee for the past year.

Respectfully submitted,

THE COMMITTEE ON RAIL.

Appendix A.

SPECIFICATIONS FOR QUENCHED CARBON AND QUENCHED ALLOY STEEL JOINT BARS.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the joint bars have been made in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspection shall be made at the place of manufacture, prior to loading, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Rejection at Destination.

3. Joint bars which show injurious defects subsequent to their acceptance at the place of manufacture or sale will be rejected and returned to the manufacturer, who shall pay the freight charges both ways.

Material.

4. Material for joint bars shall be steel made by the Open-Hearth process or an acceptable alloy steel.

Chemical Properties.

5. The chemical composition of each melt of steel from which joint bars are manufactured shall be within the following limits:

Carbon, per cent	0.42 to 0.55
Phosphorus, per cent., maximum	0.04

Note.—In the event of nickel and chromium being present to the extent of 1.00 per cent. and 0.35 per cent., respectively, these elements will be considered as the equivalent of 0.07 per cent. of carbon in the above requirements.

6. The manufacturer shall furnish the inspector a complete report of ladle analysis showing carbon, manganese, phosphorus and sulphur content of each melt represented in the finished material. The purchaser may make a check analysis from the finished material; such analysis shall conform to the requirements of Section 5.

Physical Properties and Tests.

7. Joint bars shall conform to the following physical requirements:

	Quenched Steel.	*Alloy Steel.*
(a) Tensile strength, lbs. per sq. in., minimum.	100,000	110,000
(b) Elastic limit, lbs. per sq. in., minimum....	70,000	85,000
(c) Elongation, per cent. in 2 inches, not less than	$\frac{1,600,000}{\text{Ten. Str.}}$	

Minimum, 12 per cent.

(d) Reduction in area, per cent. not less than.......... $\frac{3{,}500{,}000}{\text{Ten. Str.}}$.
Minimum, 25 per cent.

(e) Cold bending of the quenched bar without sign of fracture on the outside of the bent portion through 90 degrees around an arc, the diameter of which is three times the thickness of the test specimen.

8. All test specimens shall be cut from finished bars.

(a) The tension test specimens shall be about 4¼ inches long with threaded or unthreaded ends, and with the central 2-inch length turned to a ½-inch diameter, in accordance with the form and dimensions for tension test specimens of the American Society for Testing Materials.

(b) The bend test specimens shall be ½-inch square in section or a rectangular bar ½-inch thick with two parallel faces as rolled.

(c) The elastic limit shall be determined by the use of the Berry strain gage, or similar instrument, and will be the load when the elongation shows a change in the rate of stretch, the machine being operated at not more than ¼-inch per minute. After the elastic limit is reached the speed shall not exceed 2 inches per minute.

Quenching.

9. (a) Joint bars shall be quenched in oil, or water if so specified, from a temperature of about 810 degrees Centigrade (1490 degrees Fahrenheit) and shall be kept in the bath until cold enough to be handled. A group thus treated is known as a quenching charge.

(b) Material which requires quenching in water will be acceptable at the option of the purchaser, provided it meets the requirements of the specification in all other respects.

General Requirements.

10. Joint bars shall be rolled to dimensions specified in drawing furnished by the purchaser. No variation will be allowed in the dimensions affecting the fit and the fishing spaces of the rail. The maximum camber in either plane shall not exceed 1/32-inch in 24 inches.

11. Joint bars shall be sheared to the length prescribed by the purchaser and shall not vary therefrom by more than ⅛-inch.

12. (a) All joint bars shall be punched, slotted and shaped at a temperature of not less than 800 degrees Centigrade (1470 degrees Fahrenheit).

(b) All bolt holes shall be punched in one operation without bulging or distorting the section, and the bars shall be slotted when required for spikes in accordance with the purchaser's drawing, the slotting being done in one operation. A variation of 1/32-inch in location of the holes will be allowed.

13. All types of joint bars shall be finished smooth and true without swelling over or under the bolt holes, and shall be free from flaws, seams, checks or fins. The fishing angles shall be fully maintained.

Branding.

14. The rolled bar shall be branded or marked for identification in the following manner and a portion of this marking shall appear on each finished joint bar:

(a) A portion of the name of the manufacturer, the year of manufacture, the numbered design and the kind of material shall be rolled in raised letters and figures on the outside of the bars.

(b) The letters "O H" shall be used to indicate "Open-Hearth Steel."

(c) The letter "Q" shall be used to show that the joint bars have been "quenched." If the joint bars are also tempered, the letters "QT" shall be used to show that they have been "quenched and tempered."

(d) The number of the melt shall be plainly stenciled on each lot of bars.

Inspection.

15. The joint bars from each melt or heat treatment lot shall be piled separately until tested and inspected by the inspector. One joint bar for tension test shall be selected by the inspector for each melt or heat treatment lot represented in finished bars. One joint bar for bend test shall be selected by the inspector for each lot of 1000 bars or less presented or from each heat treatment lot.

Appendix B.

SPECIFICATIONS FOR QUENCHED CARBON AND QUENCHED ALLOY STEEL TRACK BOLTS WITH NUTS.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the bolts and nuts have been made in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspection shall be made at the place of manufacture, prior to loading, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Rejection at Destination.

3. Bolts and nuts which show injurious defects subsequent to their acceptance at the place of manufacture or sale will be rejected and returned to the manufacturer, who shall pay the freight charges both ways.

Material.

4. Material for bolts shall be steel made by the Open-Hearth process or an acceptable alloy steel. It shall be homogeneous and when broken in tension, shall show a uniformly silky fracture. Material for the nuts shall be soft, untreated steel.

Chemical Properties.

5. The chemical composition of each melt of steel from which track bolts are manufactured shall be within the following limit:

Phosphorus, per cent., maximum..............................0.04

6. The manufacturer shall furnish the inspector a complete report of ladle analysis showing carbon, manganese, phosphorus and sulphur content of each melt, represented in the finished material and any other elements used to obtain the specified physical properties. The purchaser may make a check analysis from the finished material; such analysis shall conform to the requirements of Section 5. The drillings for check analysis shall be taken parallel to the axis and from the end of the finished bolt.

Physical Properties and Tests.

7. Track bolts shall conform to the following physical requirements:

	Carbon Steel.	*Alloy Steel.*
(a) Tensile strength, lbs. per sq. in., minimum.	100,000	110,000
(b) Yield point, lbs. per sq. in., minimum....	70,000	85,000
(c) Elongation, per cent., in 2 inches, not less than	$\frac{1,600,000}{\text{Ten. Str.}}$	
Minimum, 12 per cent.		

(d) Reduction in area, per cent. not less than.......... $\frac{3,500,000}{\text{Ten. Str.}}$

(e) Cold bending of the unthreaded portion of the finished bolt without fracture on the outside of the bent portion through 90 degrees around an arc, the diameter of which is three times the thickness of the test specimen.

8. All test specimens shall be from the finished bolts.

(a) The tension test specimens shall be about 4¼ inches long with threaded or unthreaded ends, and with the central 2-inch length turned to a ½-inch diameter, in accordance with the form and dimensions for tension test specimens of the American Society for Testing Materials.

(b) The yield point shall be determined by the strain gage.

Quenching.

9. (a) Track bolts shall be treated by quenching in oil or water, if so specified, from a temperature of about 810 degrees Centigrade (1490 degrees Fahrenheit) and shall be kept in the bath until cold enough to be handled; a group thus treated being known as a quenching charge.

(b) Material which requires quenching in water will be acceptable at the option of the purchaser, provided it meets the requirements of the specification in all other respects.

General Requirements.

10. Track bolts and nuts shall be made to dimensions specified in drawing furnished by the purchaser with allowable variations in dimensions of bolts from standard as follows:

Length, ⅛-inch;
Diameter of shank, 1/64-inch;
Shoulder, 1/64-inch;
Diameter of rolled thread not more than 1/16-inch over the diameter of the body of ⅞-inch bolts;
Diameter of rolled thread not more than 3/32-inch over the diameter of the body of 1-inch bolts;
Variation in dimensions of elliptical shoulders under head of bolt of 1/32-inch.

11. The heads and nuts shall be free from checks or burrs of any kind. All finished pieces shall be smooth, straight, of uniform size, with well-shaped symmetrical bends and well-filled heads, free from injurious mechanical defects, and be finished in a first-class, workmanlike manner. The head shall be concentric with and firmly joined to the bottom of the bolt with the underside of the head at right angles to the body of the bolt. The threads on the bolts shall be rolled, unless otherwise specified, shall be full and clean and shall be made in section and pitch according to the purchaser's standard. The fit between threads on the bolt and nut shall be accurate and nut shall go on with a 10-inch wrench from second to fifth turn. The force to turn the nut completely on the bolt with a 24-inch wrench shall not be more than 60 nor less than 40 lbs.

12. (a) The nuts shall be made of soft untreated steel and shall be ¼-inch thicker than the standard nuts used for untreated bolts. They

shall be of sufficient strength to develop the ultimate breaking strength of the bolts.

(b) Nuts of standard thickness will be accepted at the option of the purchaser if proved to be of sufficient strength to equal the ultimate breaking strength of the bolts. The length of the bolts shall be correspondingly reduced.

Branding.

13. The heads of the bolts shall bear the manufacturer's identification symbol. The letter "Q" shall be used to show that the bolts have been "quenched." If the bolts are also tempered, the letters "QT" shall be used to show that they have been "quenched and tempered."

Marking and Shipping.

14. When the bolts are shipped they shall have the nuts applied for at least two threads, be well oiled to prevent rust, and shall be packed in securely hooped kegs of 200 lbs. net. All kegs shall be plainly marked as to material, size of bolts and name of manufacturer.

Inspection.

15. Tension and bend tests shall be made of the test specimens selected by the inspector from each lot of 50 kegs. One specimen shall be selected for each test, and if it meets the requirements of the specification, the lot will be accepted. If the test specimen fails, two additional specimens shall be tested in the same manner as the one which failed, and if they meet the requirements of the specification, the lot will be accepted. If, however, either one of the pieces fails, the lot will be rejected. Both tension and bend tests shall pass the requirements for acceptance.

SPECIFICATIONS FOR MEDIUM CARBON STEEL TRACK BOLTS WITH NUTS.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the bolts and nuts have been made in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspection shall be made at the place of manufacture, prior to loading, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

Rejection at Destination.

3. Bolts and nuts which show injurious defects subsequent to their acceptance at the place of manufacture or sale will be rejected and returned to the manufacturer, who shall pay the freight charges both ways.

Material.

4. Material for bolts shall be steel made by the Open-Hearth or Bessemer process. It shall be homogeneous and when broken in tension, shall show a uniformly silky fracture. Material for nuts shall be of soft steel.

Chemical Properties.

5. The chemical composition of each melt of steel from which track bolts are manufactured shall be within the following limits:

Phosphorus, Maximum.	Per Cent.
Open-Hearth	0.05
Bessemer	0.10

6. The manufacturer shall furnish the inspector a complete report of ladle analysis showing carbon, manganese, phosphorus and sulphur content of each melt represented in the finished material and any other elements used to obtain the specified physical properties. The purchaser may make a check analysis from the finished material; such analysis shall conform to the requirements of Section 5. The drillings for check analysis shall be taken parallel to the axis and from the end of the finished bolt.

Physical Properties and Tests.

7. Track bolts shall conform to the following physical requirements:

(a) Tensile strength, lbs. per sq. in., minimum	55,000
(b) Yield point not less than 50 per cent. of the ultimate breaking stress	
(c) Elongation, per cent. in 2 inches, not less than	$\frac{1,500,000}{\text{Ten. Str.}}$
Minimum, 20 per cent.	
(d) Reduction in area not less than	$\frac{2,200,000}{\text{Ten. Str.}}$
Minimum, 30 per cent.	
(e) Cold bending of the unthreaded part of the finished bolt without sign of fracture on the outside of the bent portion, through 180 degrees flat on itself.	

8. All test specimens shall be from the finished bolts.

(a) The tension test specimens shall be about 4¼ inches long with threaded or unthreaded ends, and with the central 2-inch length turned to a ½-inch diameter, in accordance with the form and dimensions for tension test specimens of the American Society for Testing Materials.

General Requirements.

9. Track bolts and nuts shall be made to dimensions specified in drawing furnished by the purchaser, with allowable variation in dimensions of bolts from standard as follows:

Length, ⅛-inch;
Diameter of shank, 1/64-inch;
Shoulder, 1/64-inch;

Diameter of rolled thread not more than 1/16-inch over the diameter of the body of ⅞-inch bolts;

Diameter of rolled thread not more than 3/32-inch over the diameter of the body of 1-inch bolts;

Variation in dimensions of elliptical shoulders under head of bolt of 1/32-inch.

10. The heads and nuts shall be free from checks or burrs of any kind. All finished pieces shall be smooth, straight, of uniform size, with well-shaped symmetrical bends and well-filled heads, free from injurious mechanical defects, and be finished in a first-class, workmanlike manner. The head shall be concentric with and firmly joined to the bottom of the bolt, with the underside of the head at right angles to the body of the bolt. The threads on bolts shall be rolled, unless otherwise specified, shall be full and clean and shall be made in section and pitch according to the purchaser's standard. The fit between threads on the bolt and nut shall be accurate and nut shall go on with a 10-inch wrench from second to fifth turn. The force to turn the nut completely on the bolt with a 24-inch wrench shall not be more than 60 nor less than 40 lbs.

11. The nuts shall be made of soft, untreated steel and shall be of sufficient strength to develop the ultimate breaking strength of the bolts.

Branding.

12. Manufacturer's identification shall appear on the head of each bolt.

Marking and Shipping.

13. When the bolts are shipped they shall have the nuts applied for at least two threads, be well oiled to prevent rust, and shall be packed in securely hooped kegs of 200 lbs. net. All kegs shall be plainly marked as to material, size of bolts and name of manufacturer.

Inspection.

14. Tension and bend tests shall be made of the test specimens selected by the inspector from each lot of 50 kegs. One specimen shall be selected for each test, and if they meet the requirements of the specifications the lot will be accepted. If one of the test specimens fails, two additional specimens shall be tested in the same manner as the one which failed, and if they meet the requirements of the specifications, the lot will be accepted. If, however, either one of the specimens fails, the lot will be rejected. Both tension and bend tests shall pass the requirements for acceptance.

(For Appendices C, D, E, and F,

pp. 427-492, see Bulletin 199, September, 1917.)

Appendix G.

INHIBITED OR DELAYED TRANSFORMATIONS IN RAIL HEADS.

ASSOCIATED WITH TWO OR MORE CONDITIONS OF THE STEEL, INDICATED BY CORES OR ZONES.

By Dr. P. H. Dudley,
Consulting Engineer, New York Central Lines.

I mentioned cores and gave one illustration in "Report No. 59 to Rail Committee," American Railway Engineering Association, November, 1916. The zones have been disclosed in the individual work of cutting and breaking into small fragments the drop test pieces of the heads of rails in which interior transverse fissures of rails have developed in the track.

I have not found in any of the numerous publications on metallography or those on steel, a word in reference to the practical difficulties the steel for rails must undergo on the hot beds to complete all of the complex transformations as rolled from the hot set ingots through the critical range of temperatures for Austenite, and cool through those for Martensite, Troostite, Sorbite and Pearlite on the hot beds.

Troosite and Sorbite while minor, yet essential transformations in the rail steel, have less ductility than Pearlite and increase in volume during transformation to Pearlite. Therefore, when traces of either Troostite or Sorbite remain as a core or in a zone in the interior of the surrounding envelope of Pearlite, which has transformed and expanded, the core or zone may be under sufficient initial strain to become physically non-ductile metal, as is found to be the case in rail heads.

When the normal chemical composition for rail is above the eutectic, Cementite will be precipitated as the metal recalesces with loss of ductility in the steel.

Austenite is the designation for the condition of the metal as Gamma iron at a temperature of about 900° C., in which the carbon is in solution, but the steel as Austenite cannot be held by quenching in the carbon content for rails. The metal requires from 1.10 to 1.80 carbon and then quenched at 1000° C.

Austenite is secured in Manganese rails with a carbon content of 1.00 to 1.35 and 10 to 14 per cent. manganese to cause a lag in the transformations and then quenched at about 1000° C. It can be scratched, yet it is so tough that it cannot be drilled and is abraded slowly, though readily deformed on account of its low elastic limit.

Rail steel can be quenched at a proper temperature and held as Martensite, and then tempered for Troostite or Sorbite, or lower, for a fine texture—the basis of heat treatment for rails.

Rail Report 68, December, 1917.

The transformation in steel from Austenite to Martensite is so instantaneous and complete, a general impression prevails that the other three transformations in rail steel on the hot beds to Pearlite, must be equally as complete. This may have been found true in laboratory specimens of small forged or rolled bars of similar carbon steels, but it is not found true in the head of an occasional rail as it cools upon the hot beds, for something has inhibited the transformations, as are now found to be the fact.

The hot open-hearth steel is rolled in bars of 3 to 5 rail lengths and, when sawed, each rail goes through the cambering machine, which curves the head around the base to induce them to cool low or nearly straight on the hot bed. The rails do not cool as intended, for some leave the hot beds low, in irregular curves, with side sweeps, while others are high, and some are low on one end and high upon the other. The hot bed work at present does not receive the attention basic open-hearth rails require.

The sections of present rails have from 8 to 13 square inches of metal, and even when distributed in equal weight for the base and head, the latter from its form, is more massive, while the base of any section is the first to start recalescence on the hot beds. This causes the base to expand and curve around the head, which straightens the rail, and continues to curve until the rail is low upon the hot bed, then the head undergoes the effect of its recalescence, restraightens the rail and continues to curve around the base, more than the original camber.

The cooling of the rails on the hot beds takes from 30 to 35 minutes, while the distinct recalescence of the base and then of the had, occupies from 6 to 15 minutes, and produces movements back and forth for the entire rail length, causing irregular spacing of the rails. (See Table No. 1.)

Something in this period of cooling and decalescence may inhibit or delay the requisite transformations in—

First, an occasional cold rolled rail head.

Second, in an occasional rail head which contains traces of slag inclusions.

These two causes have been found to inhibit the transformations on the hot beds so far in the investigations, and others may be disclosed as the research proceeds.

These inhibited or delayed transformations cause a loss of ductility of the metal in the interior of the head, which may be located in some rail heads in almost a continuous longitudinal line near the central portion, while in others it may only be in a core nearer the outside, and then change to the other side in a few inches. This seems to depend upon the practice of turning the rails on the hot beds.

The rail heads in which interior transverse fissures have developed in the track after two to six years of service are now tested under a drop for brittleness or ductility. Brittle pieces of rail heads on being partially cut by a hack saw and the interior broken as a transverse, or split as a longitudinal section, often disclose cores or zones in the metal of a different macroscopic and microscopic appearance from that of its surrounding steel.

The zones are sometimes ⅜ to ⅝ of an inch wide, and three-fourths of the width of the interior portion of the rail head.

These cores, due to initial strains, with the enclosing metal, may become in effect, physically non-ductile or heterogeneous metal in the rail heads, as stated in my first descriptions. These zones are sometimes associated with striated longitudinal layers of more than the average phosphorus of 0.02 or 0.03 content and minute inclusions of slag. Such layers have been found in the nuclei of both the Intergranular and Coalescent types of transverse fissures, and appear in etchings or sulphur prints as a white band in the rail heads. This tentative description will doubtless require elaboration and revision as the investigation proceeds.

The entrained slag in small globules in the ingots, is extended 20 or more times in length in the rail heads and is due to the reactions of the metal in the ladle where the time allowed was too short for the slag to collect in masses, and escape from the bath before the steel was teemed into the ingot molds. The molten steel after being recarburized or resiliconized, should stand at least ten minutes before teeming the ingots, to permit the reactions in the steel to complete themselves and the slag escape.

These white bands seem to be due to checking the falling temperatures of a small zone of interior molten metal in the ingots when they are charged into the reheating furnaces. This permits a short period of selective freezing to occur in the zone before setting, and the initial heat equalized for blooming and rolling. These white bands have not been found in rail heads of ingots properly treated with 0.1 per cent. of metallic titanium, which causes a quiet and rapid setting of the steel.

The ingots for rail steel must be stripped and charged into the reheating furnace before the interior metal has set sufficiently to form a shrinkage cavity and pipe below the usual discard.

The recent work on these cores or zones in the metal, is to take pieces of the rail heads in which they are included, and heat them in an electric furnace to 910° C., for 25 or more minutes, and then cool in the air to simulate hot bed conditions.

One piece, No. 268-1-A-B, L., rolled 12-29-10, Heat No. 3811, "A" rail, which had been sawed and broken transversely and raised to 910° C., for 25 minutes and cooled in the air, the core of the characteristic texture of the nuclei of the Intergranular type of interior transverse fissure, did not complete its transformation, while its surrounding steel was coarser in texture—a more advanced degree of transformation.

A second piece, No. 274-1-E, rolled 11-14-10, Heat No. 20584, "B" rail, of another brand, was put into the electric furnace and raised to 910° C., then maintained for 40 minutes and the specimen cooled in the air between two similar hot rail heads of the same temperature. It required 13 minutes for the metal to lose its red color.

The dimensions of the core were reduced in spots, but not completely effaced. Some of the distinctive texture persisted in places. The longer time of heating and cooling was effective to produce transformations in portions of the core.

This procedure has been applied to many other specimens with like results. Heating and cooling curves on numerous specimens of cold-rolled rails and those containing slag inclusions all show inhibited or delayed transformations.

Two different rails from the same melt of steel in which interior transverse fissures of the Intergranular type developed in the track, the nuclei were well defined crystals or grains as checked between them by the gag, while the growth of the fissure from the checked periphery of the nuclei was *through* the grains.

This feature of the checked nuclei between the grains before the fissure starts to develop from its periphery, distinguishes it from the so-called "fatigue fracture" produced by gagging beyond the elastic limits of the steel, along the length of the rail, first on the base, and then on the head or vice versa. Associated in the metal of the heads of the two rails in which sharply defined crystals were found in the nuclei of the fissures, were single or groups of two or more crystals interspersed in a small central area of the head, and a few at the junction of the head and web.

This suggests the queries: What were the conditions in the metal and of the heating of the ingots which would germinate single crystals or groups of two or more, in the hot set steel? Why was not the entire mass of the metal affected at the same time? The other rail from the same melt, the crystals near the junction of the head and web were heat tinted in what was a slight longitudinal check in the metal.

These observations of facts in the manufacture of rails are important to be noted.

60-Inch Supports in the Straightening Presses.

Comparative tests of the pressure on my 105-lb. rail on 42 and 60 inch supports, were about 50,000 lbs. less for the longer span, with a reduction of the shearing stresses over the supports.

One mill has used a press with 60-inch supports for several months and like it so much that a second press with similar supports has been constructed. Another mill has tried 54-inch supports on two presses, and expect to go to 60-inch supports for heavy sections. The supports will be made adjustable for both heavy and light sections, for the tonnage of such rails is still an important item in manufacture.

Experience and Co-operation.

The Manufacturers and the Railroad Companies have had several years' experience with basic open-hearth steel rails to replace those of

Bessemer of 0.10 phosphorus. The breakages of open-hearth rails are several times less than Bessemer in the latitudes where cold winters occur.

It is the conclusion of some Manufacturers, as well as the Railroad Companies, that the small percentage of interior transverse fissures in open-hearth rails, is still too large, and must be eliminated.

The function of the rail as a girder in manufacture, as well as in service in the track, is being recognized, and manufacturers who once recommended about 1 per cent. of carbon as the upper limit for wear, no longer do so, and Engineers who still wish chemical compositions in rails which will precipitate Cementite on cooling, are advised that such practice is no longer desirable.

The New York Central Lines, to check the rapid deformation of the rail heads by the contours of the present cast iron wheels, have returned to a contour of 1 in 38 for the full width of the tread, except a ⅝-inch radius for the sand chill.

This is essential to establish proper relations between the wheel contacts on the rails and distribute the wheel loads to more metal in the rail heads and wear the bearing surface its full width, as occurred before the present narrow width of contour was adopted for cast iron wheels.

TABLE 1.

COOLING AND RECALESCENCE OF OPEN-HEARTH RAILS ON HOT BEDS.

(Time in minutes and seconds.)

Date	Mill	Section	Rail	Starting Straight	Straight	Low	Straight	High	Remarks
2–10–16	No. 1	6″–105# Dudley	D	1:35	2:35	4:15	7:00	10:10	Turned 6:15 Spacing bet. bars 12″.
			E	5:25	6:50	7:20	9:35	13:15	
			F	4:55	6:00	7:20	8:05	10:10	
2–17–16	No. 1	90# A.R.A. "A"	H	4:40	5:20	6:00	7:45	9:35	Bars spaced 12″
			G	5:50	6:15	6:35	9:05	12:15	
			F	3:35	6:25	7:00	9:55	13:45	
			E	1:30	2:20	4:45	7:10	11:25	
2–24–16	No. 1	85# A. S. C. E.	A	1:50	4:10	5:05	6:48	9:40	Bars spaced 12″.
			B	5:20	5:40	7:00	9:45	12:10	
			C	5:20	5:40	7:00	8:55	11:40	
			D	3:50	4:45	5:20	7:20	8:20	
2–25–16	No. 1	80# A. S. C. E.	A	1:20	2:35	6:00	7:05	9:45	Turned 5:25 Bars spaced 12″.
			B	5:05	5:30	6:25	8:20	11:25	
			C	4:45	5:20	6:25	8:05	10:55	
			D	4:25	5:10	6:15	7:15	9:10	
1–24–16	No. 2	7″–120# Dudley	A	2:10	4:05	6:10	6:45	10:55	First Bar No. 4 Bed.
			B	3:40	6:55	7:40	9:25	14:00	
			C	3:20	6:25	7:20	7:55	12:10	
1–25–16	No. 2	125# P. S.	A	5:10	6:45	7:50	8:45	11:00	Center #3 Bed Bars spaced15″ Turned 10:45.
			B	3:30	7:40	8:25	10:30	15:00	
			C	2:20	3:10	4:45	7:50	14:30	
1–7–15	No. 2	6″–105# Dudley	A	1:45	3:02	6:30	7:15	16:30	#4 Bed-Middle
			B	4:10	6:10	8:58	10:05	16:40	
			C	5:00	6:20	8:58	10:00	17:30	
			D	4:05	5:45	7:30	7:45	17:45	
12–19–14	No. 3	6″–105# Dudley	2	1:40	5:15	7:30	8:45	11:35	#4 Bed.
			1	4:38	6:48	7:20	9:18	11:35	
12–19–14	No. 3	6″–105# Dudley	2	1:40	5:57	7:10	7:53	10:30	#4 Bed.
			1	5:45	6:30	7:20	8:27	10:30	

Appendix H.

INTENSITY OF PRESSURE ON RAILS.

REPORT ON RATIONAL RELATION BETWEEN INTENSITY OF PRESSURE DUE TO WHEEL LOADS AND RESISTANCE OF RAIL STEEL TO CRUSHING AND DEFORMATION.

J. R. ONDERDONK, *Chairman;* A. W. GIBBS,
DR. P. H. DUDLEY, M. H. WICKHORST,
Sub-Committee.

The following is a report of a Sub-Committee of the Rail Committee of the American Railway Engineering Association on Subject 8, assigned by the Board of Direction.

The most obvious effects of the pressure are, of course, the well-known crushing of the heads, particularly at the ends, the flow of metal in the soft heads, and the deep vertical splitting of the heads in so many cases of failure. Of course, there are many variants of these typical failures, with which we are all entirely too familiar.

OUTLINE OF INVESTIGATION.

After a full discussion of the most promising methods of attacking the problem, it was decided that the investigation should include both laboratory and field tests.

Laboratory Tests.

1. To attempt an exploration of the interior of the head of the rail after subjecting it to definite repetitions of rolling loads.

2. So far as possible, to define the area of contact between the rail and the wheel at different periods throughout the test.

3. To determine the hardening effect of the rolling load on the contact and adjacent surfaces.

Field Tests.

To be made with regular locomotive, tender, and car equipment.

1. To determine as far as possible the areas of contact between rails and wheels whose contours were known.

2. To determine the distribution of the intensity of pressure within the area of contact.

The Field Tests were undertaken by Dr. P. H. Dudley.

Rail Report 69, December, 1917.

The data upon which this report is based, and from which the graphics have been prepared, are very full and in good shape. They are too voluminous to be printed, but will be available to anyone interested in the subject.

The Committee wishes to acknowledge the valuable assistance of:

M. A. Knapp, Assistant to Dr. Dudley.

C. B. Bronson, Mechanical Engineer for Dr. Dudley.

W. H. Tapman, Mechanical Inspector for the Baltimore & Ohio Railroad Test Bureau.

J. R. Fetterly, Inspector for the Pennsylvania Railroad Test Department.

Also, its thanks are due F. W. Wood, General Manager of the Maryland Plant of the Bethlehem Steel Company, for his co-operation and kindness in furnishing the use of the reciprocating machine for the Sparrows Point tests.

CONCLUSIONS.

For the present, the only conclusions that can be drawn from the tests which have been made are but indications:

Field Tests.

1. That for this section and composition of rail initial loads of 30,000 pounds or more per wheel of cast iron and chilled tread, of 33 inches in diameter, were too great for the transverse holes, and produced flow or closure at least ⅜-inch below the bearing surface.

2. That loads of 25,000 pounds produced but slight flow or closure in the three uppermost transverse holes, and this extending not more than ¼-inch in depth.

3. That preliminary light loads, by cold-rolling the surface, may adapt the material to subsequent heavier loads.

Laboratory Tests.

4. The diagrams of the plotted tables show that the stresses in the metals are locally less severe than we had expected to find in the surfaces of the pressure zone contacts of the wheel tread and the rail head.

5. It is important, as the theory and evidence show, that the metal of the circumjacent layer of each pressure zone of contact for the wheel tread, also that of the rail head, is in position not only to utilize the elasticity of the metal to help carry a given load, but to increase in area within the elastic limits of the metals nearly in proportion to the loads applied.

6. The action of the rolling wheels on the rail heads is a gradually applied load from zero to the maximum, then reducing again to zero, both for a unit length in the wheel tread or rail head, and is not a suddenly applied load, even for a mile-a-minute or faster trains.

7. The *round* type of area of contact shows the greatest average unit intensity of pressure.

8. The *longitudinal oval,* or the *transverse oval* type indicates the lowest average unit intensity of pressure.

9. The *longitudinal elliptical* or *transverse elliptical,* in which the major axis is two or more times the width of the minor axis, indicates also a favorable average unit of intensity of pressure.

10. The *transverse oval* or *elliptical* under steel or cast-iron wheels is more favorable for the rail heads than the *round.*

11. The reciprocal relations of the loads carried on the metal of the wheel treads to the metal of the rail heads, should be studied from the voluminous service tests now available.

PART I—LABORATORY TESTS.

Testing Machines.

For this work the Committee availed itself of the kind offer of the Bethlehem Steel Company of the rolling test machine at its Sparrows Point plant.

This machine is shown in Figs. 1, 2 and 3, and consists, briefly, of a heavy bedplate on which is reciprocated a very strong steel platen on roller bearings. The rail to be tested is secured to the reciprocating platen, to which motion is given by a motor driven crank shaft and pitman. The machine is run at the rate of 10 to 14 double passes—20 to 28 passes—per minute. The load is applied by linkage of multiplying levers and weights through a chilled iron car wheel running on roller bearings. Your Committee did not calibrate this machine.

Note.—If further work is done on a reciprocating machine, it will be desirable to load the machine by direct weights, eliminating the combination of levers. While this will be cumbersome, it will avoid the necessity of such careful shimming as was required in the tests already made.

Rail.

The rail selected was a new 100-pound P. S. section, open-hearth steel, made by the Cambria Steel Company for the Pennsylvania Railroad, its chemical composition and physical characteristics being given in the reports of tests, Figs. 3A and 3B and illustrations, Figs. 3C and 3D.

The drop tests made by the Pennsylvania Railroad Company at the mill, and the drop tests made by the Baltimore & Ohio Railroad Company on their rail testing machine, showed that the rails in both cases stood the same number of blows, they breaking on the fifth blow, and the total elongation on the fourth blow was the same in each case.

The analyses are shown as made by the Manufacturer, by the Baltimore & Ohio Railroad and by the Pennsylvania Railroad at Altoona, Pa. These all check quite closely, and in connection with the sulphur prints, scleroscope readings and Brinnell readings indicate that the rails were of uniform quality and, furthermore, that the manufacturer's tests check very closely with the results of the rail received.

It was believed that if this rail were drilled in different directions under the surface, the load deformation, if any occurred, could be measured. It was decided that the rail should be drilled transversely at different distances from the upper running surface with holes parallel to the base, the holes to be of the smallest practicable diameter and fitted with tapered, turned and ground steel plugs. Also, for the purpose of investigating lateral flow, as well as the behavior of the metal immediately under the tread, that holes upwardly inclined should be drilled in the lower corner of the head and similarly fitted with plugs. Finally, that each test piece, of which there were two, should be drilled vertically from base to head with a similar small hole, by means of which it was hoped that the depth of the rail under contact could be measured by micrometer depth gage placed below, to develop the form of the dished surface within the area included in the contact spot.

The section of the rail used and the locations of the different holes are shown by Figs. 4, 5, 6 and 7.

The centers of the horizontal holes were placed below the surface of the tread approximately $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$ and $\frac{3}{8}$ inch, the actual depths being shown by Figs. 8 and 9, in the belief that the flow, if any, would be within this range of depth. The holes were $\frac{3}{32}$-inch diameter, reamed to standard taper.

Each hole was fitted with its own headed and lettered taper plug. Each plug was divided by marking rings approximately $\frac{1}{8}$-inch apart, so that the difference in diameter at each ring was approximately .001 inch. Each plug (nine in all) was carefully calibrated and the calibration recorded. (See Figs. 10 and 11).

The preparation of the test pieces and the plugs, through the kindness of Mr. J. T. Wallis, General Superintendent of Motive Power, Pennsylvania Railroad, was entrusted to the Tool Room at the Juniata Shops, Altoona, Pa. This preparation called for a very high grade of workmanship, and was very excellently accomplished, which aided materially in obtaining satisfactory results.

In making the tests the rail was placed on the machine, resting directly on an oak liner less than one inch in thickness, special care being taken that the running surface of the rail should be as nearly as practicable parallel with the base of the platen, so that the weights imparting the load would remain as nearly as possible stationary.

At stated intervals the machine was stopped and the plug gages inserted and deviations from the original depth of penetration of the tapered holes recorded. In addition to the record of any closure of the holes as revealed by the taper plugs, data was recorded of the width of contact as shown on the rail, as well as the distance between the boundary of the line of contact and the gage side of the rail.

To determine the effect of any surface hardening of the rail due to the contact on the head, scleroscope readings were taken across the head at the ends, entirely outside of the travel of the rail, and at four other points transverse to the head, within the length of travel of rail, and hardness readings were made within and without the area of contact. The total length of the rail specimens was 5 feet, and the total travel of the rail approximately 4 feet. (See Figs. 12 and 13.)

Observers were detailed from the Test Departments of the Baltimore & Ohio and the Pennsylvania Railroads, so as to check on one another.

RESULTS OF THE TESTS.

First Test.—The first test was made beginning with a wheel load of 30,000 pounds, which was maintained during the first 110,000 passes of the rail under the wheel. The load was then increased to 35,000 pounds, with which load 120,000 additional passes were run.

To the surprise of the Committee, the first fifty passes of the wheel indicated that all of the horizontal holes were closing, and by the time 500 passes had been run all of the horizontal holes had closed by amounts varying from .001 to .003 inch in diameter. From this point the closure of the deeper holes became very slow. After the application of the 35,000-pound load the closure of all of the holes became more marked. This is shown graphically in Fig. 14.

The width of the area of contact of the wheel is shown graphically by Fig. 15, and the location from the gage side is shown by Fig. 16. The area of contact of the wheel resting on the rail was also taken at intervals, beginning at 5,000 passes, then at 10,000, and after that at each 20,000 passes throughout the test. The result is shown graphically by Fig. 17. The width of contact apparently diminished during the first few passes, after which it steadily increased as the wheel tread and rail head conformed. The diminution was probably caused by the breaking down of the mill scale. For the same reason the area of contact between the wheel and the rail increased, as indicated by Figs. 18 to 26, inclusive, showing the form of the spot at the beginning of the test, at the end of the 30,000-pound loading, and at the end of the run with 35,000 pounds.

Second Test.—As the initial passes of the wheel over the first rail specimen indicated an immediate closure of the holes, this closure extending so as to include even the deepest hole—⅜-inch below the surface—it was decided to start the test of the second specimen with a light load of but 15,000 pounds, and increase the loading to, successively, 20,000, 25,000 and 30,000 pounds, or more. This was done and the same data taken as with the first rail.

With the 15,000-pound load 25,000 passes were run, no closure whatever being observed. The load was then increased to 20,000 pounds, with which 26,000 passes were run without producing any closure. During this period of a total of 51,000 passes, however, the width of contact constantly increased and the path of contact gradually extended toward the gage side of the head. The load was then increased to 25,000 pounds, with which 110,000 passes were run, very slow closure of from

.0005 to .0015 being noted in the holes nearest the tread. The load was then increased to 30,000 pounds, with which 105,000 passes were run, the result being an additional closure of from .0005 to .0012 inch in the holes nearest the top of the rail, but no closure of the deeper holes, namely, those 5/16 inch and ⅜ inch from the tread, was measurable during the entire test.

At this point the machine test had to be discontinued, owing to the pressure for shop room for other machine tools.

The salient point is that with an initial load of 30,000 pounds an immediate closure or flow of metal, penetrating at least ⅜ inch from the tread, was noted within the first few passes, and that by the time 110,000 passes had been run all of the holes had closed by amounts varying from .0035 inch in the deeper holes to .0085 inch for the holes nearer the surface; while, on the other hand, as already stated, in the case of the preliminary light loads very little effect was noted until the application of the 30,000-pound load, and the closure under that load never reached the deeper holes, and in the shallower ones produced not over one-fifth of the closure noted during the same service in the first test.

This would seem to have a direct bearing on the statement so often made, that the light rails rolled many years ago are better than the present-day rails, because they are still in service, carrying the present-day loads with fewer failures than we experience with the new and heavy rail. It has been suggested by Maintenance of Way engineers that the early light service has, by cold rolling, prepared the surface of the rail for subsequent heavier service.

The scleroscope readings, as tabulated and shown graphically, clearly indicate an immediate hardening of the surface under the wheel, and that this hardness gradually increased during the test; and there is no proof that the maximum hardness due to cold rolling had been reached at the termination of either test.

Other Deformation.—The measurement of the test holes other than those parallel to the base indicates hardly any perceptible flow; the maximum closure, that of hole "M," first test, being but .00036 inch.

While the method of investigation described affords a delicate method of measuring the depth at which the material is flowing under load, there is the open question whether the flow occurred because there was an unoccupied hole into which the metal under load could flow. This method does not measure the direction in which the flow moves—it may be radial closing of the hole, or it may be a crushing down of the roof. Nor does it show clearly at what point in the length of the hole the closure occurs, though this might be accomplished by a number of short taper sections of gage, each of which would explore part of the hole.

It is expected that these test rails will be placed in a freight track carrying a heavy coal tonnage, and that in time they will give further information.

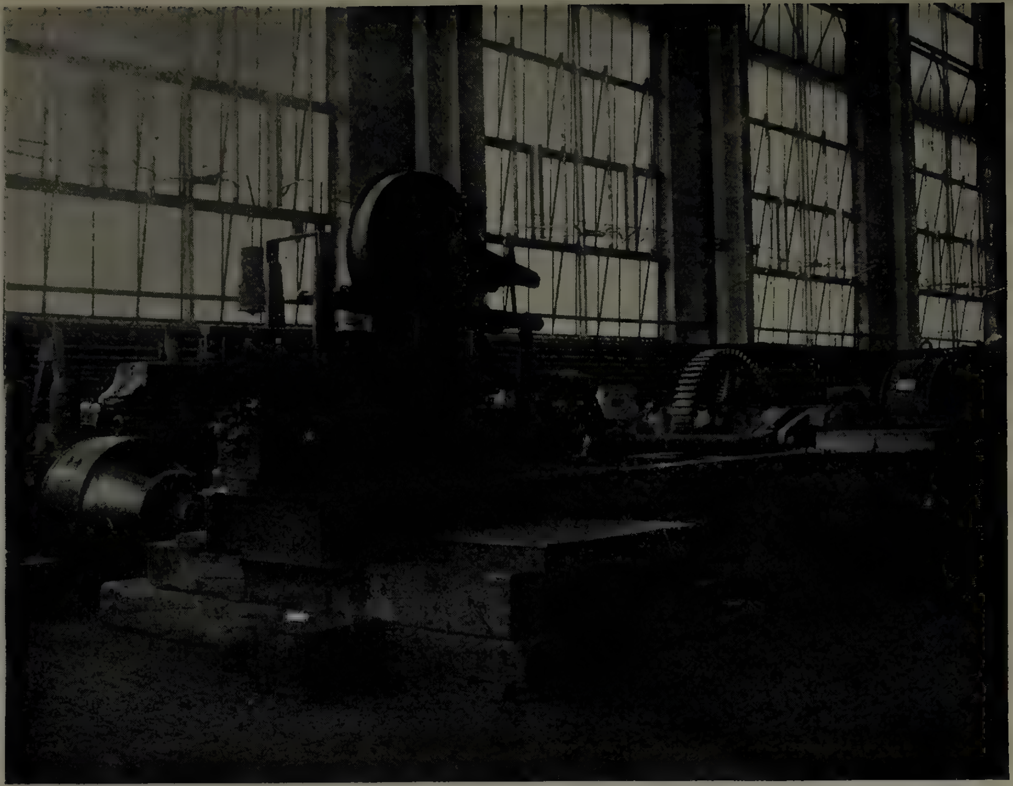


FIG. 1.—GENERAL VIEW OF RECIPROCATING MACHINE AND DRIVING MECHANISM.

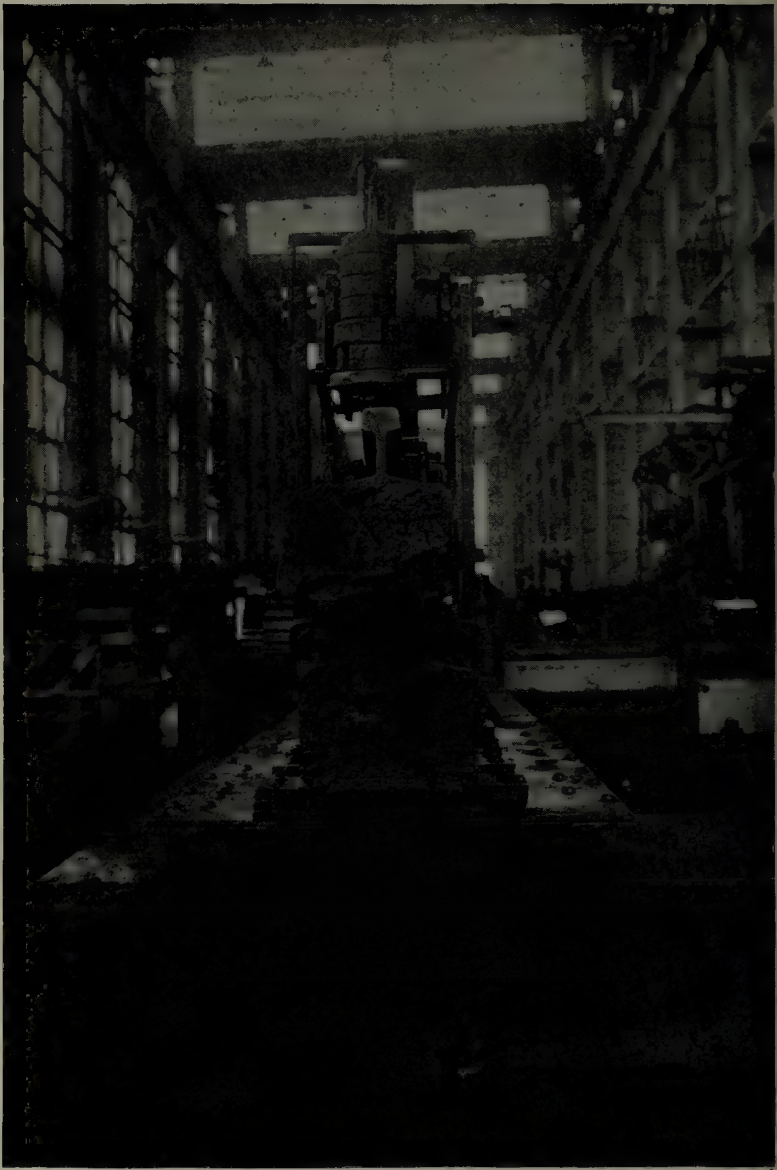
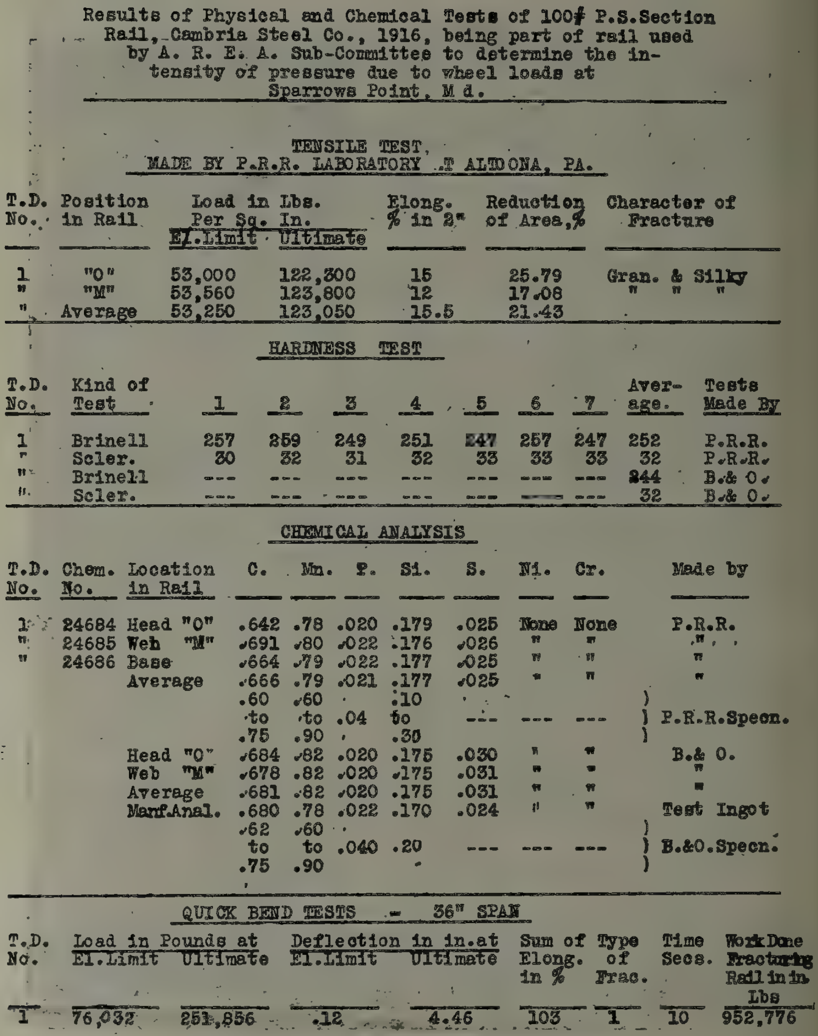


FIG. 2.—END VIEW OF RECIPROCATING MACHINE.

FIG. 3.—VIEW OF RECIPROCATING MACHINE SHOWING PLUG GAGES IN SIDE OF RAIL.



Results of Physical and Chemical Tests of 100# P.S.Section Rail, Cambria Steel Co., 1916, being part of rail used by A. R. E. A. Sub-Committee to determine the intensity of pressure due to wheel loads at Sparrows Point, M d.

TENSILE TEST,
MADE BY P.R.R. LABORATORY .T ALTOONA, PA.

T.D. No.	Position in Rail	Load in Lbs. Per Sq. In. El.Limit	Load in Lbs. Per Sq. In. Ultimate	Elong. % in 2"	Reduction of Area,%	Character of Fracture
1	"O"	53,000	122,300	15	25.79	Gran. & Silky
"	"M"	53,560	123,800	12	17.08	" " "
"	Average	53,250	123,050	15.5	21.43	

HARDNESS TEST

T.D. No.	Kind of Test	1	2	3	4	5	6	7	Average.	Tests Made By
1	Brinell	257	259	249	251	247	257	247	252	P.R.R.
"	Scler.	30	32	31	32	33	33	33	32	P.R.R.
"	Brinell	---	---	---	---	---	---	---	244	B.& O.
"	Scler.	---	---	---	---	---	---	---	32	B.& O.

CHEMICAL ANALYSIS

T.D. No.	Chem. No.	Location in Rail	C.	Mn.	P.	Si.	S.	Ni.	Cr.	Made by
1	24684	Head "O"	.642	.78	.020	.179	.025	None	None	P.R.R.
"	24685	Web "M"	.691	.80	.022	.176	.026	"	"	"
"	24686	Base	.664	.79	.022	.177	.025	"	"	"
		Average	.666	.79	.021	.177	.025	"	"	"
			.60 to .75	.60 to .90	.04	.10 to .30	---	---	---	P.R.R.Specn.
		Head "O"	.684	.82	.020	.175	.030	"	"	B.& O.
		Web "M"	.678	.82	.020	.175	.031	"	"	"
		Average	.681	.82	.020	.175	.031	"	"	"
		Manf.Anal.	.680	.78	.022	.170	.024	"	"	Test Ingot
			.62 to .75	.60 to .90	.040	.20	---	---	---	B.&O.Specn.

QUICK BEND TESTS - 36" SPAN

T.D. No.	Load in Pounds at El.Limit	Load in Pounds at Ultimate	Deflection in in.at El.Limit	Deflection in in.at Ultimate	Sum of Elong. in %	Type of Frac.	Time Secs.	Work Done Fracturing Rail in in. Lbs
1	76,032	251,856	.12	4.46	103	1	10	952,776

FIG. 3A.—LABORATORY TESTS OF RAILS.

DROP TEST
AT MANUFACTURER'S PLANT AT TIME OF INSPECTION

Test No.	Ingot No.	Blow No.	Per. Set	Elongation Each Inch						Total Elong.	Fracture	Remarks
				1	2	3	4	5	6			
1	2	1	1.3	3	4	5	5	4	4	25	O.K.	N. & B.
2	M	1	1.3	3	4	4	5	5	4	25	O.K.	N. & B.
3	L	1	1.3	2	4	5	5	4	3	23	----	---
"	"	2	2.2	4	6	8	7	6	5	36	----	---
"	"	3	3.7	3	9	12	18	14	10	65	----	---
"	"	4	4.1	8	13	17	18	16	13	85	----	---
"	"	5	Bk.	-	--	--	--	--	--	--	O.K.	Twisted

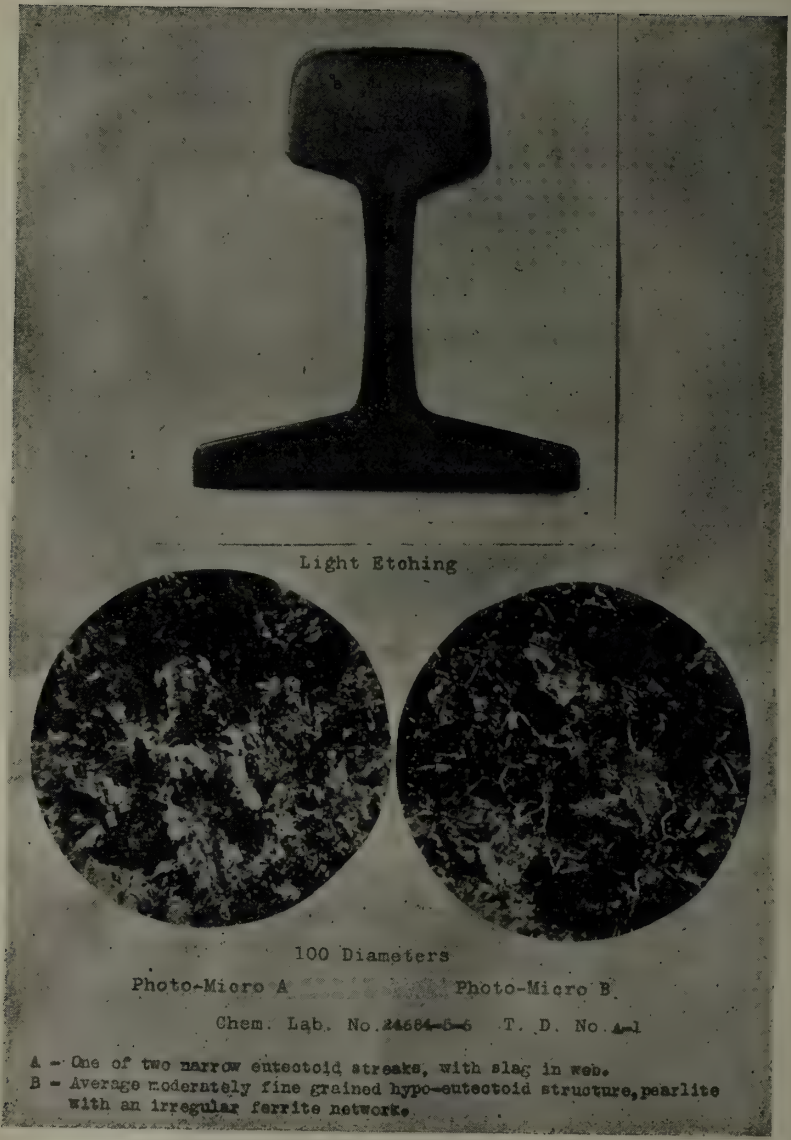
DROP TEST
ON PIECE OF TEST RAIL ON BALTIMORE & OHIO TEST MACHINE

Test No.	Ingot No.	Blow No.	Per. Set	Elongation Each Inch						Total Elong.	Fracture	Remarks
				1	2	3	4	5	6			
4	-	1	1.00	4	5	4	4	3	5	25	----	---
"	-	2	1.95	8	9	9	8	7	9	49	----	---
"	-	3	2.85	11	13	12	10	10	13	69	----	---
"	-	4	3.65	13	15	16	14	11	16	85	----	---
"	-	5	Bk.	14	Bk.	16	14	11	16	--	O.K.	----

TEST PIECE TAKEN FROM "B" RAIL OF INGOT.

ALL DROP TESTS MADE WITH 2,000 Lbs. WEIGHT FALLING 18-FT.
A.R.E.A. TESTING MACHINE.

FIG. 3B.—DROP TESTS.



Chem. Lab. No. 24684-5-6 T. D. No. A-1

A - One of two narrow eutectoid streaks, with slag in web.

B - Average moderately fine grained hypo-eutectoid structure, pearlite with an irregular ferrite network.

FIG. 3C.—ETCHING AND PHOTOMICROGRAPHS.

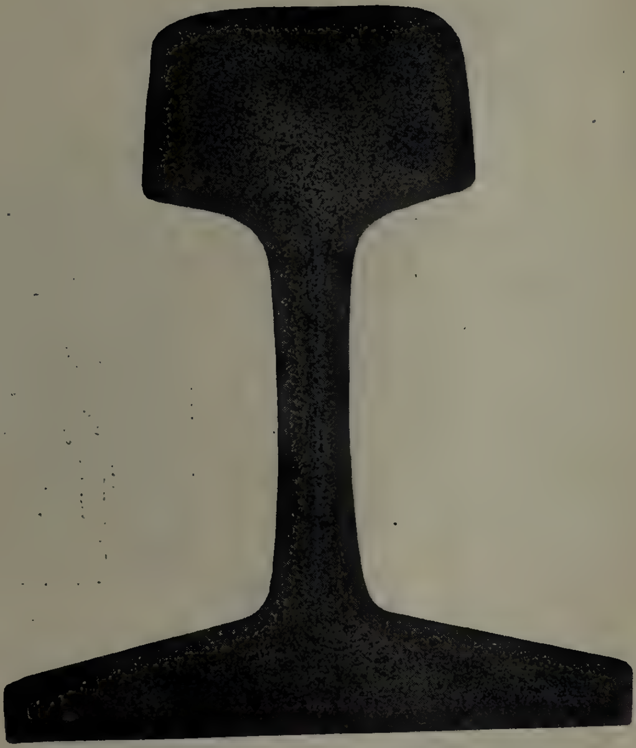
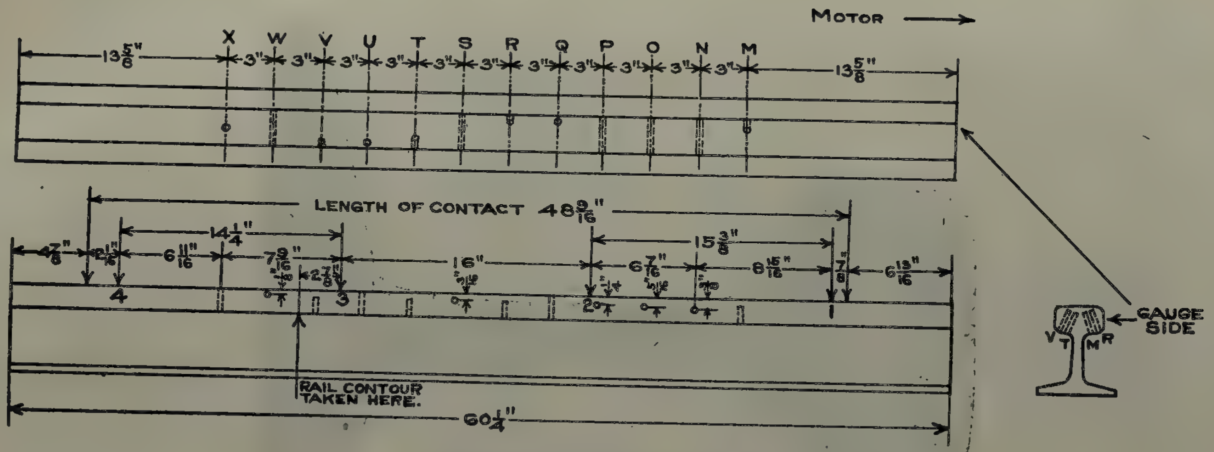


Fig. 3D.—Reproduction from Sulphur Print.



DISTANCE FROM TOP OF RAIL TO CENTER OF HORIZONTAL HOLES.

HOLE	NOMINAL DISTANCE	ACTUAL DISTANCE	DIFF.
N	0.375	0.391	+0.016
O	0.312	0.297	−0.015
P	0.250	0.2345	−0.016
S	0.187	0.187	0.0
W	0.125	0.157	+0.032

FIG. 4.—LOCATIONS OF HOLES IN RAIL M.

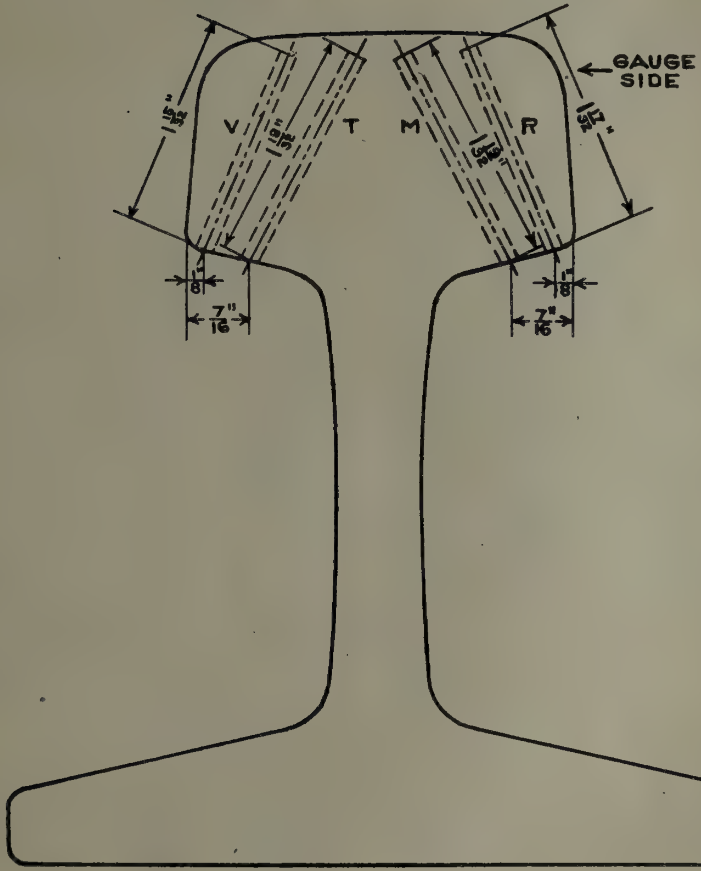


DIAGRAM SHOWING POSITION OF HOLES V, T, M, & R.

FIG. 5.

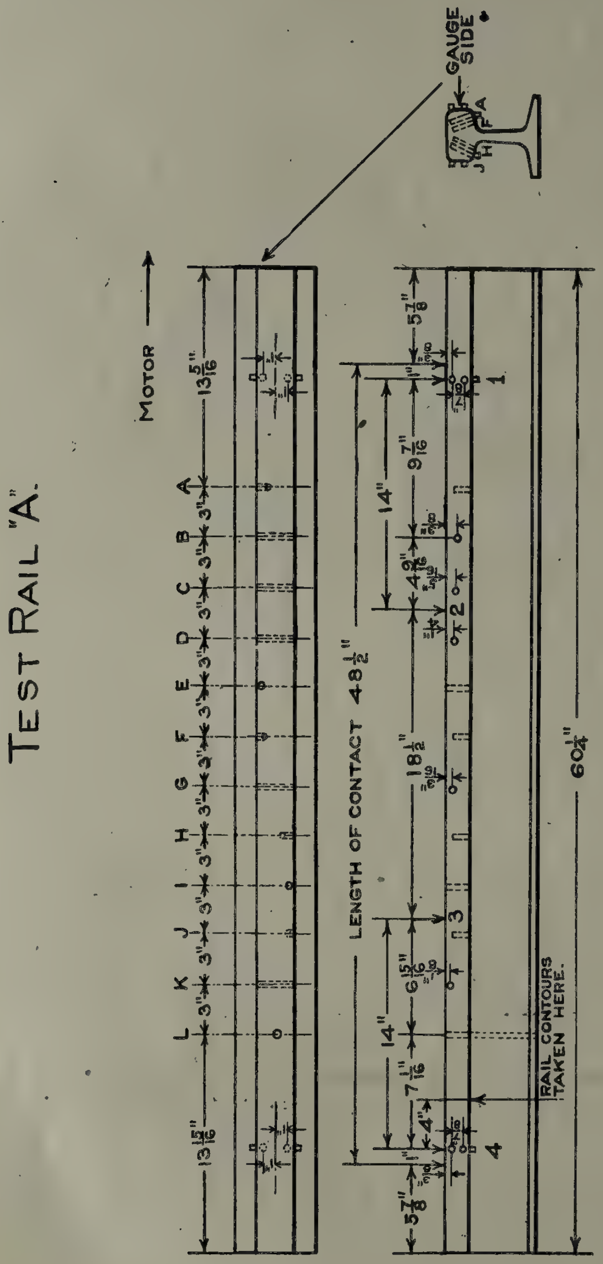

TEST RAIL "A".
MOTOR
GAUGE SIDE
A
B
C
D
E
F
G
H
I
J
K
L
13$\frac{5}{16}$"
3"
13$\frac{5}{16}$"
LENGTH OF CONTACT 48$\frac{1}{2}$"
14"
9$\frac{7}{16}$"
5$\frac{7}{8}$"
4$\frac{9}{16}$"
18$\frac{1}{2}$
6$\frac{15}{16}$"
7$\frac{1}{16}$"
4"
1"
1
2
3
4
60$\frac{1}{4}$"
RAIL CONTOURS TAKEN HERE.

Fig. 6.

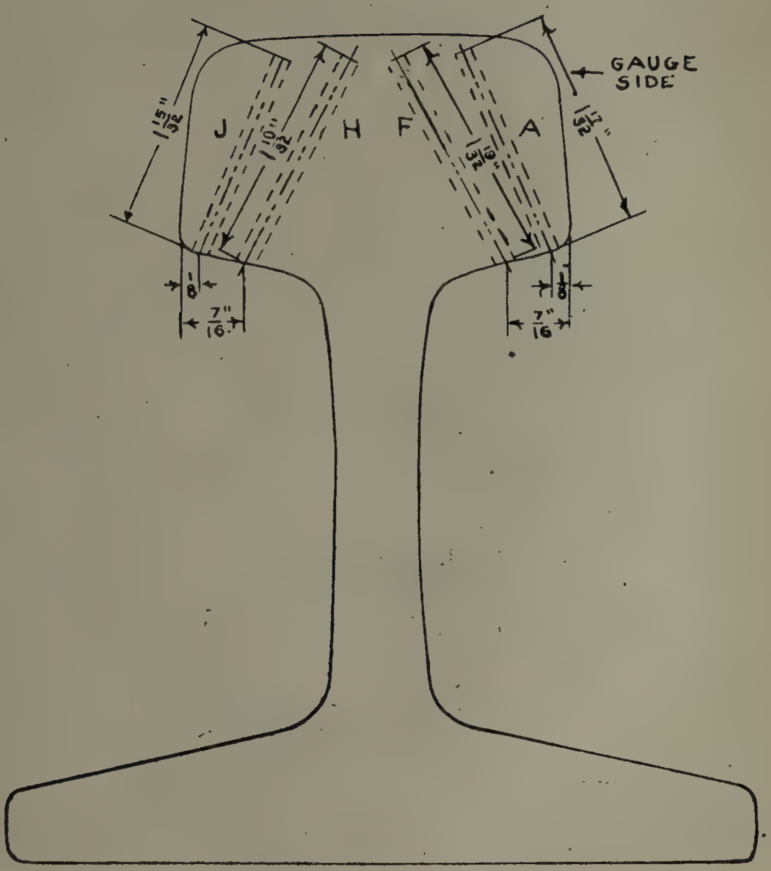


DIAGRAM SHOWING POSITION OF HOLES J, H, F, & R.

FIG. 7.

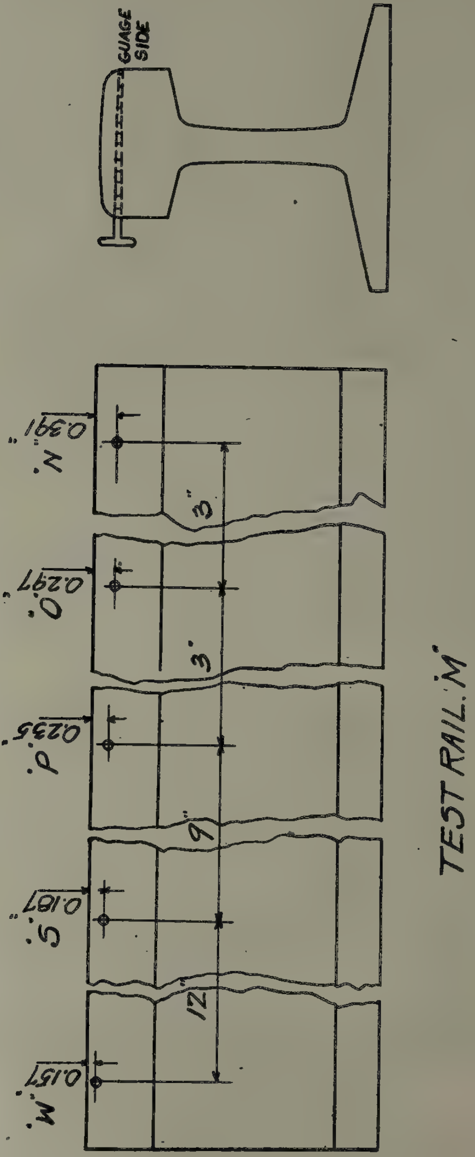
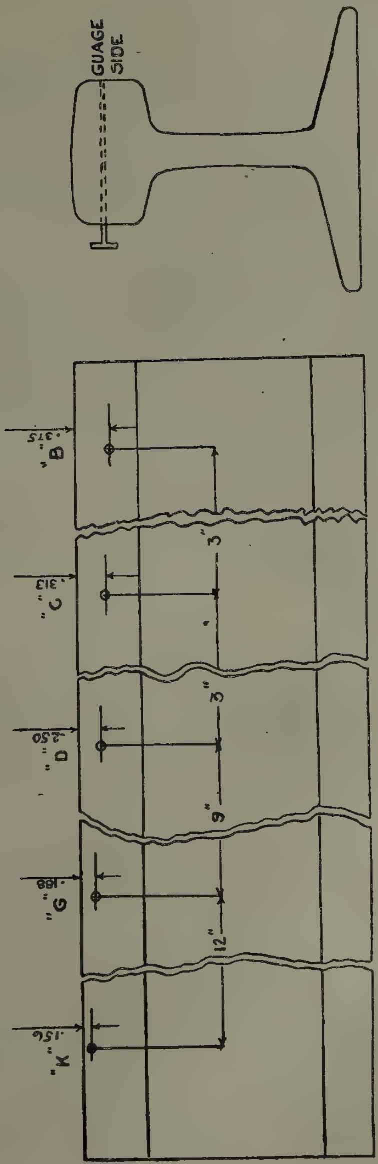
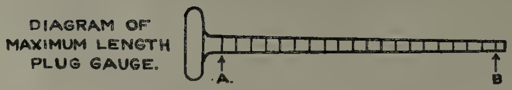


Fig. 8.—Locations of Holes.



TEST RAIL "A"

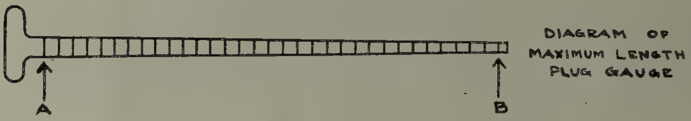
Fig. 9.—Locations of Holes.



PLUG GAUGE LETTER	M	N	O	P	R	S	T	V	W
NUMBER OF WHOLE DIVISIONS ON PLUG GAUGE	12	19	19	19	11	19	12	11	18
DIAMETER AT SMALLEST RING (RING "B")	.096"	.094"	.095"	.095"	.096"	.095"	.096"	.095"	.094"
DIAMETER AT LARGEST RING (RING "A")	.107"	.113"	.114"	.114"	.105"	.114"	.108"	.104"	.113"
DIFFERENCE IN DIAMETERS	.011"	.019"	.019"	.019"	.009"	.019"	.012"	.009"	.019"
TOTAL LENGTH OVER DIVISIONS	1.50"	2.39"	2.375"	2.36"	1.368"	2.36"	1.50"	1.375"	2.243"
DISTANCE BETWEEN EACH DIVISION	.125"	.1257"	.125"	.1242"	.1244"	.1242"	.125"	.125"	.1246"
DIFFERENCE IN DIAMETER PER LENGTH OF EACH DIVISION	.000917"	.001000"	.001000"	.001000"	.000818"	.001000"	.001000"	.000818"	.001060"

2-12-17

Fig. 10.—Plug Gage Data.

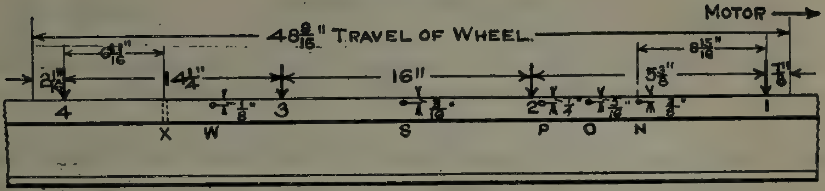


PLUG GAUGE LETTER	NUMBER OF SPACES ON PLUG	DIAMETER AT LARGEST RING	DIAMETER AT SMALLEST RING	DIFFERENCE IN DIAMETERS	LENGTH BETWEEN EACH SPACE	TOTAL LENGTH OVER SPACES	DIFF. IN DIAMETER PER LENGTH OF DIVISION
A	12	.1082"	.0963"	.0119"	.125"	1.500"	.000992"
B	32	.1155"	.0842"	.0313"	.125"	4.000"	.000978"
C	32	.1155"	.0846"	.0309"	.125"	4.000"	.000966"
D	32	.1155"	.0840"	.0315"	.125"	4.000"	.000985"
F	12	.1098"	.0977"	.0121"	.125"	1.500"	.000100"
G	32	.1155"	.0848"	.0307"	.125"	4.000"	.000959"
H	12	.1098"	.0960"	.0138"	.125"	1.500"	.001150"
K	32	.1157"	.0842"	.0315"	.125"	4.000"	.000985"
J	12	.1086"	.0965"	.0121"	.125"	1.500"	.001000"

4-17-17.

Fig. 11.—Plug Gage Data.

DATA.



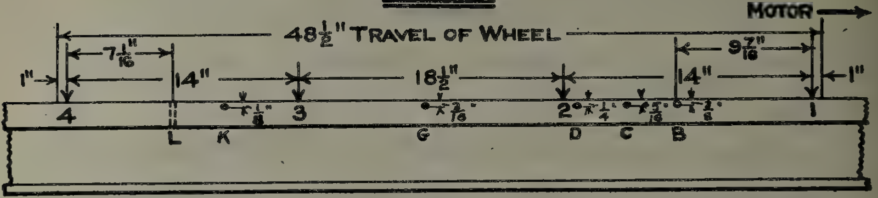
SKETCH SHOWING POSITIONS 1, 2, 3 AND 4 AT WHICH "WIDTH OF CONTACT", "LOCATION OF CONTACT" AND "AREA OF CONTACT" ARE TAKEN.

READING NO.	WHEEL LOAD	NO. OF PASSES OF WHEEL	WIDTH OF CONTACT				LOCATION OF CONTACT FROM GUAGE SIDE.				POSITION OF HOLES.											
			1	2	3	4	1	2	3	4	M	N	O	P	Q	R	S	T	U	V	W	X
2-6-17 1	0	0	0	0	0	0	0	0	0	0	1.2	1.4	1.6	2.4		0.9	2.9	1.6		1.2	2.1	
2-6-17 2	30000	50	–	–	–	–	–	–	–	–	1.2	2.0	2.8	3.7		0.9	3.8	1.6		1.2	4.4	
2-6-17 3	30000	500	1.000 ★	.875 ★	.8125 ★	.8125 ★	.6875 ★	.625 ★	.625 ★	.6875 ★	1.3	4.4	5.2	5.8		0.9	4.0	1.6		1.2	5.1	
2-8-17 4	30000	1000	.8437	.8125	.656	.593	.625	.656	.6875	.750	1.3	4.4	5.2	5.8		0.9	4.9	1.4		1.2	5.7	
2-8-17 5	30000	1500	.8437	.8125	.750	.593	.625	.656	.656	.750	1.3	4.3	5.2	5.8		0.9	4.9	1.6		1.2	6.6	
2-9-17 6	30000	3500	.860	.860	.8125	.625	.625	.593	.6564	.735	1.3	4.4	5.2	5.7		0.9	5.5	1.5		1.2	6.7	
2-10-17 7	30000	5500	.844	.906	.796	.625	.625	.593	.656	.735	1.3	4.6	5.3	5.7		0.9	5.8	1.5		1.2	6.9	
2-12-17 8	30000	10500	.8903	.890	.8125	.640	.625	.656	.656	.719	1.3	4.8	5.3	5.8		0.9	5.9	1.6		1.2	8.4	
2-13-17 9	30000	15500	.937	.906	.844	.735	.593	.593	.625	.625	1.3	4.6	5.2	5.8		0.9	6.0	1.6		1.2	8.6	
2-14-17 10	30000	20500	.870	.922	.844	.750	.593	.593	.625	.625	1.4	4.8	5.2	5.8		0.9	5.8	1.6		1.2	8.6	
2-15-17 11	30000	25500	.970	.906	.844	.750	.593	.577	.625	.625	1.4	4.8	5.2	5.9		0.9	6.8	1.6		1.2	8.7	
2-16-17 12	30000	35500	1.062	.992	.844	.750	.577	.577	.625	.625	1.4	4.6	5.3	5.9		0.9	6.9	1.5		1.3	9.5	
2-20-17 13	30000	50000	1.125	.969	.906	.781	.531	.577	.625	.625	1.5	4.7	5.2	5.9		0.9	7.8	1.5		1.2	9.5	
2-23-17 14	30000	70000	1.140	.985	.985	.844	.531	.577	.625	.593	1.5	4.8	5.5	6.0		0.9	8.6	1.5		1.2	9.8	
2-28-17 15	30000	90000	1.156	1.000	1.000	.860	.531	.562	.593	.593	1.5	4.7	5.6	6.1		0.9	9.1	1.6		1.2	10.0	
3-2-17 16	30000	110000	1.187	1.031	1.031	.969	.515	.562	.625	.578	1.5	4.8	5.7	6.2		0.9	9.5	1.6		1.2	10.0	
3-7-17 17	35000	130000	1.281	1.062	1.045	1.015	.500	.562	.610	.578	1.5	4.9	5.9	6.2		0.9	10.4	1.5		1.2	10.2	
3-9-17 18	35000	150000	1.327	1.156	1.093	1.031	.469	.531	.593	.562	1.6	4.9	5.9	6.7		0.9	11.1	1.5		1.2	10.7	
3-13-17 19	35000	170000	1.375	1.172	1.156	1.077	.469	.500	.577	.515	1.6	4.9	6.3	7.1		0.9	11.2	1.6		1.2	10.8	
3-15-17 20	35000	190000	1.390	1.218	1.202	1.110	.437	.468	.531	.515	1.6	5.1	6.3	7.3		0.9	11.5	1.5		1.2	11.2	

★ NOTE: THESE DIMENSIONS ARE IRREGULAR AND NOT IN LINE WITH THE SUCCEDING READINGS DUE TO THE CRUSHING DOWN OF THE MILL SCALE ON THE HEAD OF THE RAIL.

FIG. 12.—DATA OF TESTS, FEBRUARY 6 TO MARCH 15, 1917.

DATA.



SKETCH SHOWING POSITIONS 1, 2, 3 AND 4 AT WHICH "WIDTH OF CONTACT", "LOCATION OF CONTACT" AND "AREA OF CONTACT" ARE TAKEN.

READING NUMBER	WHEEL LOAD	NO. OF PASSES OF WHEEL	WIDTH OF CONTACT				LOCATION OF CONTACT FROM GAUGE SIDE.				PLUG GAUGE READINGS POSITION OF HOLES.								
			1	2	3	4	1	2	3	4	A	B	C	D	F	G	H	J	K
4-20-17 1	15000	0	—	—	—	—	—	—	—	—	1.6	2.0	1.9	2.4	3.3	2.5	1.5	3.3	2.7
4-21-17 2	15000	50	.327	.343	.343	.593	1.093	1.093	.907	.6875	1.6	2.0	1.9	2.4	3.3	2.5	1.5	3.3	2.7
4-23-17 3	15000	500	.4375	.281	.390	.4375	.968	1.125	.9375	.781	1.6	2.0	1.9	2.4	3.3	2.5	1.5	3.3	2.7
4-23-17 4	15000	1000	.4375	.281	.390	.4375	.968	1.140	.9375	.781	1.6	2.0	1.9	2.4	3.3	2.5	1.5	3.3	2.7
4-24-17 5	15000	1500	.4375	.281	.390	.4375	.968	1.140	.922	.781	1.5	1.9	1.9	2.3	3.3	2.5	1.5	3.3	2.7
4-24-17 6	15000	3500	.4375	.281	.390	.453	.968	1.140	.922	.781	1.5	1.8	1.9	2.3	3.3	2.5	1.5	3.3	2.7
4-25-17 7	15000	5500	.4375	.297	.4375	.453	.968	1.140	.890	.781	1.5	1.8	1.9	2.3	3.3	2.5	1.5	3.3	2.6
4-26-17 8	15000	10500	.485	.297	.4375	.453	.953	1.140	.890	.781	1.5	1.8	1.9	2.2	3.3	2.5	1.5	3.3	2.7
4-27-17 9	15000	15500	.485	.297	.4375	.453	.953	1.140	.890	.781	1.5	1.8	1.9	2.2	3.3	2.5	1.5	3.3	2.6
4-30-17 10	15000	20500	.515	.422	.4375	.485	.953	1.078	.890	.750	1.5	1.8	1.9	2.3	3.3	2.5	1.5	3.3	2.7
5-1-17 11	15000	25500	.515	.422	.5000	.5000	.953	1.078	.844	.735	1.5	1.8	1.9	2.2	3.3	2.5	1.5	3.3	2.6
5-1-17 12	20000	25550	.515	.422	.500	.500	.953	1.078	.844	.735	1.5	1.8	1.9	2.2	3.3	2.5	1.5	3.3	2.7
5-1-17 13	20000	26000	.515	.422	.500	.500	.953	1.078	.844	.735	1.5	1.8	1.9	2.3	3.3	2.5	1.5	3.3	2.7
5-1-17 14	20000	26500	.625	.422	.500	.500	.907	1.078	.844	.735	1.5	1.9	1.9	2.2	3.3	2.5	1.5	3.3	2.7
5-2-17 15	20000	27000	.625	.422	.500	.500	.907	1.078	.844	.735	1.5	1.9	1.9	2.2	3.3	2.5	1.5	3.3	2.7
5-2-17 16	20000	29000	.640	.4375	.531	.500	.892	1.062	.8125	.735	1.5	1.8	1.9	2.3	3.3	2.5	1.5	3.3	2.7
5-3-17 17	20000	31000	.656	.4375	.546	.610	.892	1.062	.8125	.735	1.5	1.9	1.9	2.3	3.3	2.5	1.5	3.3	2.7
5-3-17 18	20000	36000	.719	.500	.640	.640	.843	1.015	.781	.719	1.5	1.8	1.9	2.3	3.3	2.5	1.5	3.3	2.7
5-4-17 19	20000	41000	.719	.500	.640	.656	.843	1.015	.781	.719	1.5	1.9	1.9	2.2	3.3	2.5	1.5	3.3	2.7
5-7-17 20	20000	46000	.7343	.5625	.640	.6718	.843	.9843	.781	.7156	1.5	1.9	1.9	2.2	3.3	2.5	1.5	3.3	2.7

FIG. 13.—DATA OF TESTS, APRIL 20 TO MAY 7, 1917.

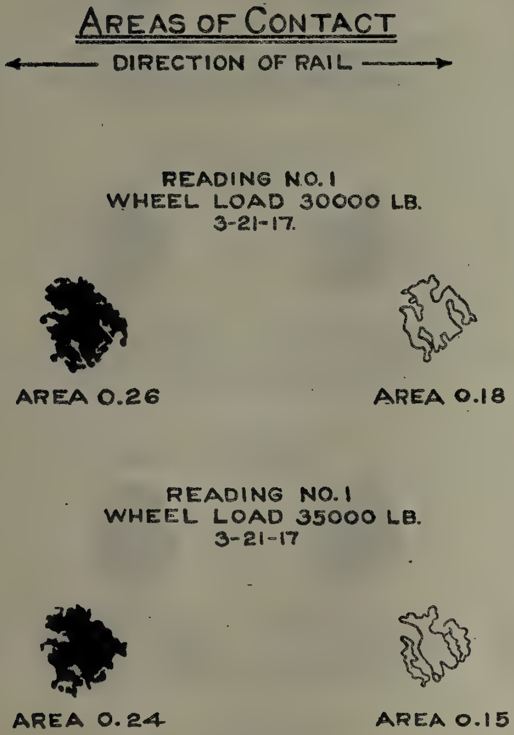


Fig. 18.

(Two-thirds Natural Size.)

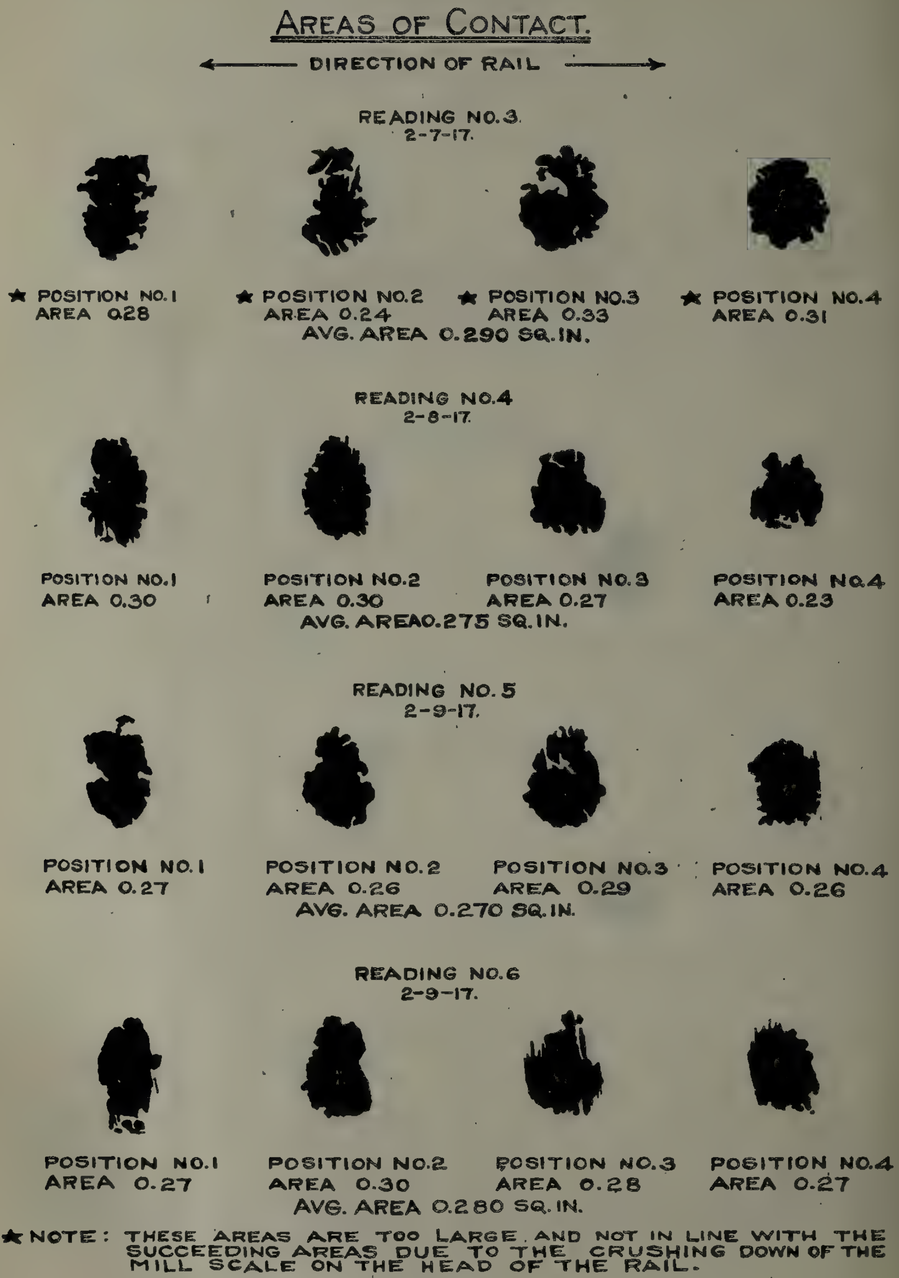


FIG. 19.

(Two-thirds Natural Size.)

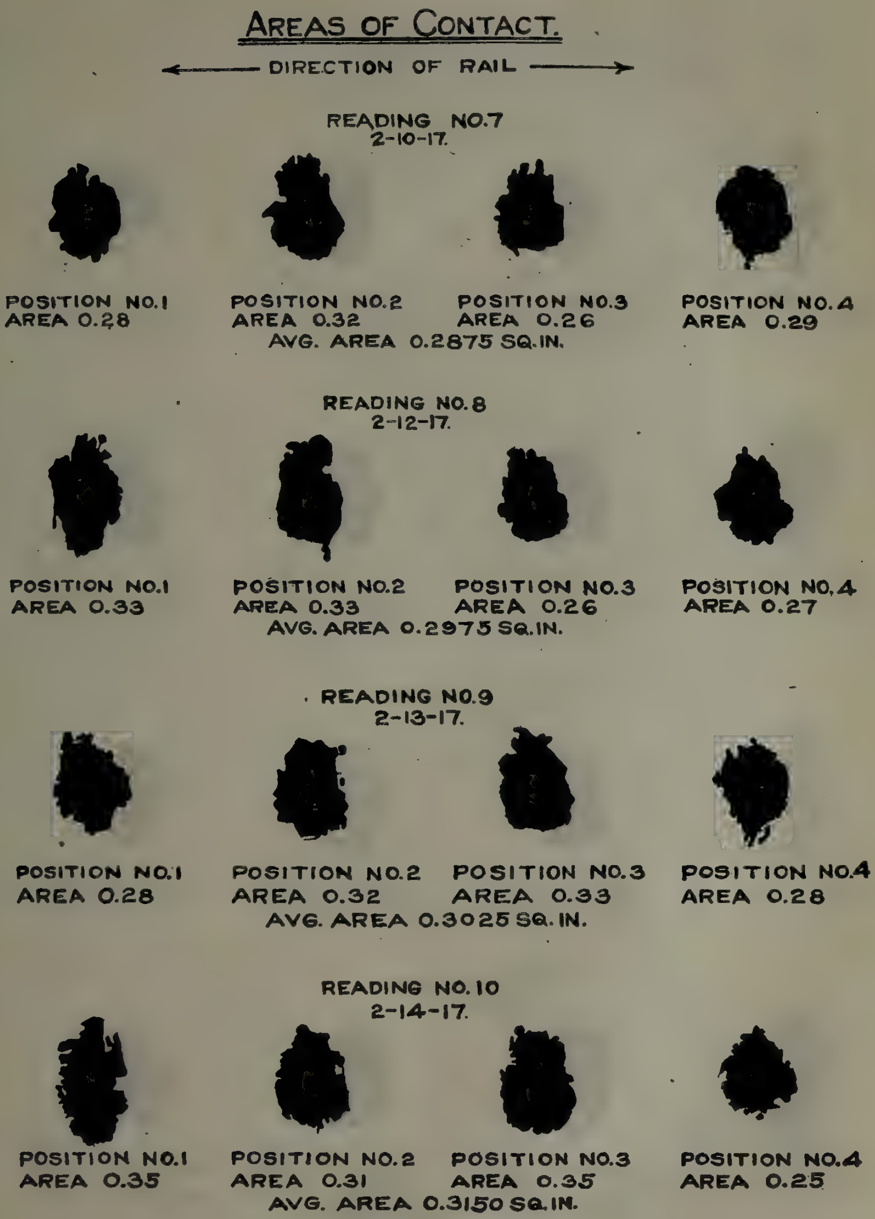


FIG. 20.

(Two-thirds Natural Size.)

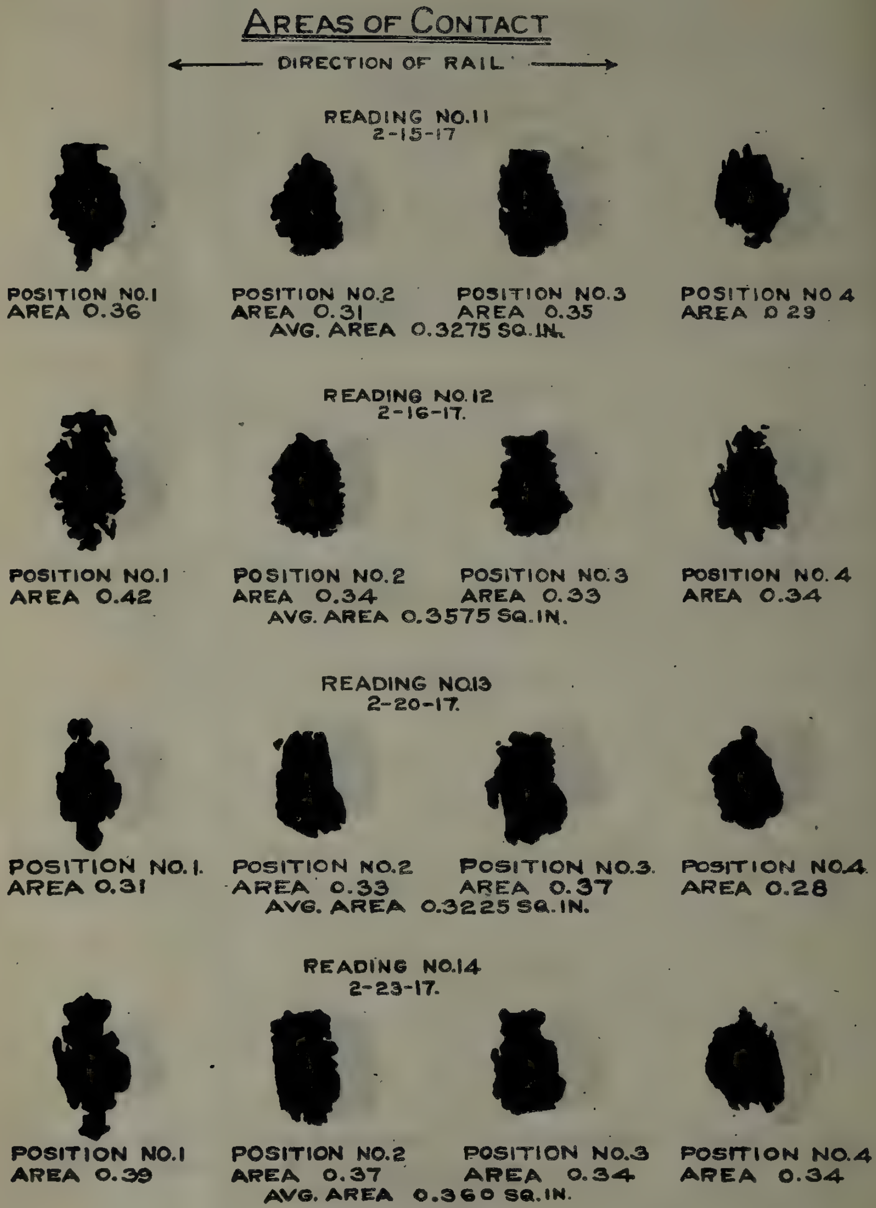
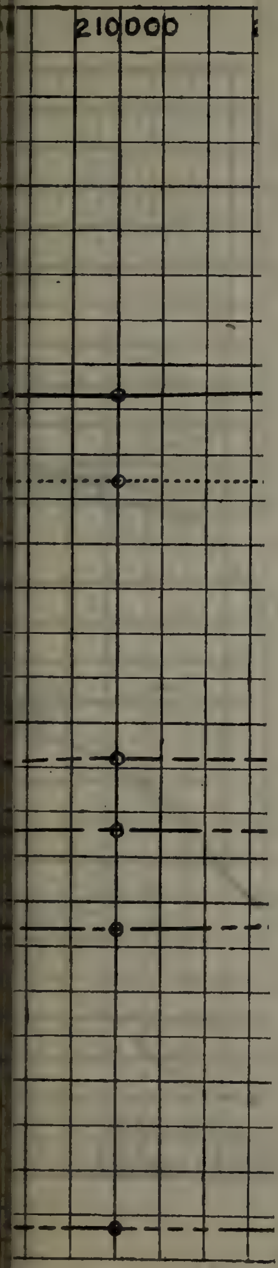


Fig. 21.

(Two-thirds Natural Size.)


210000

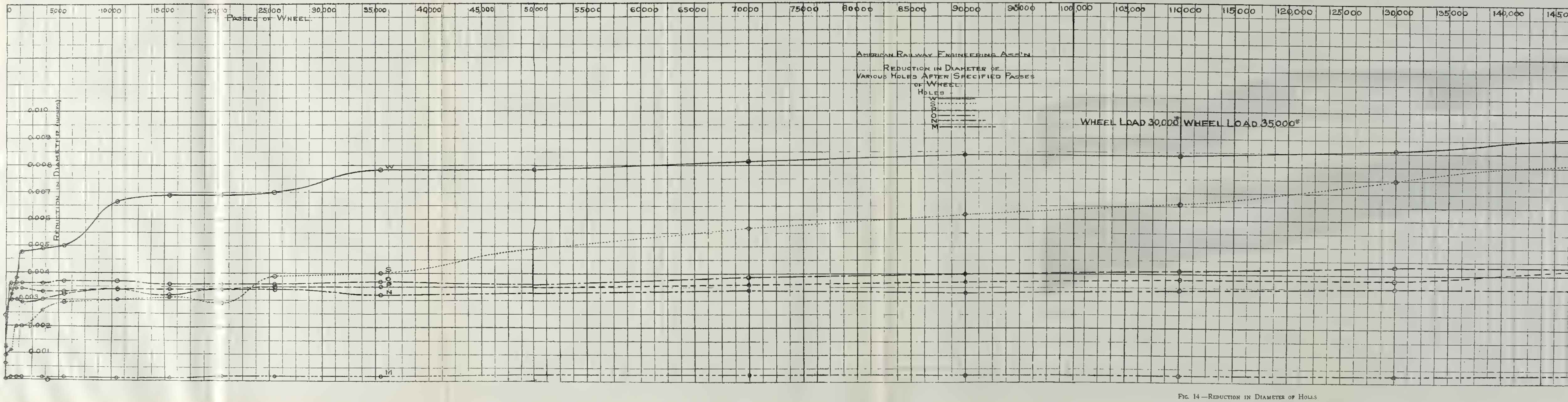
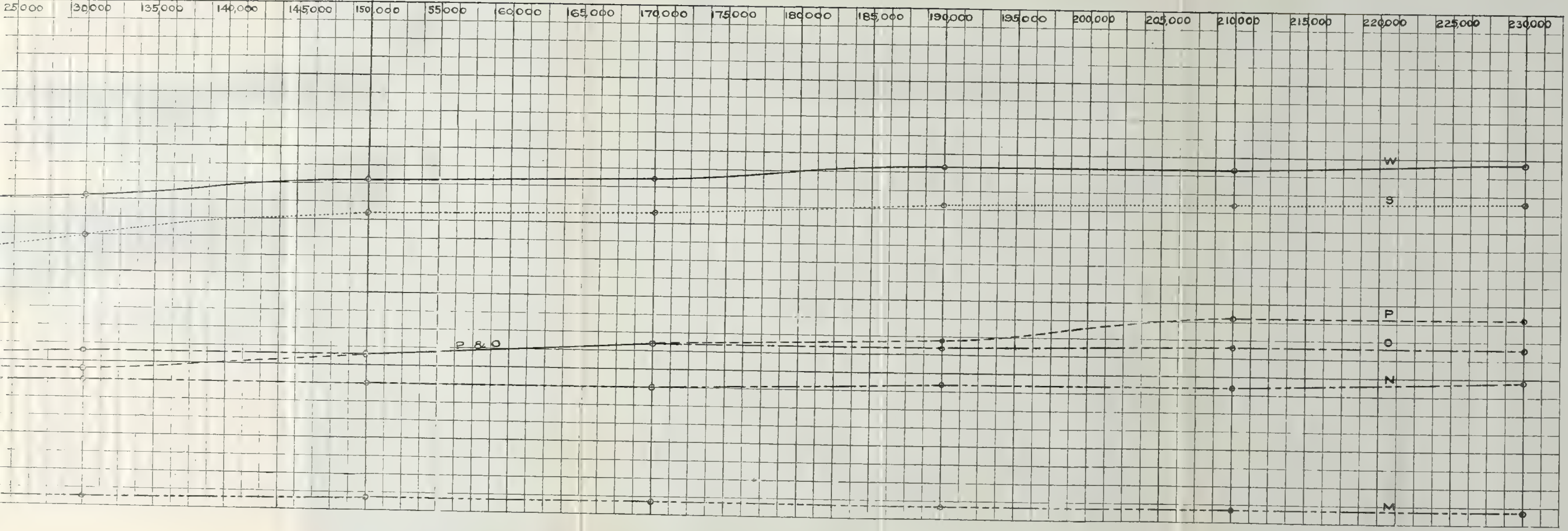
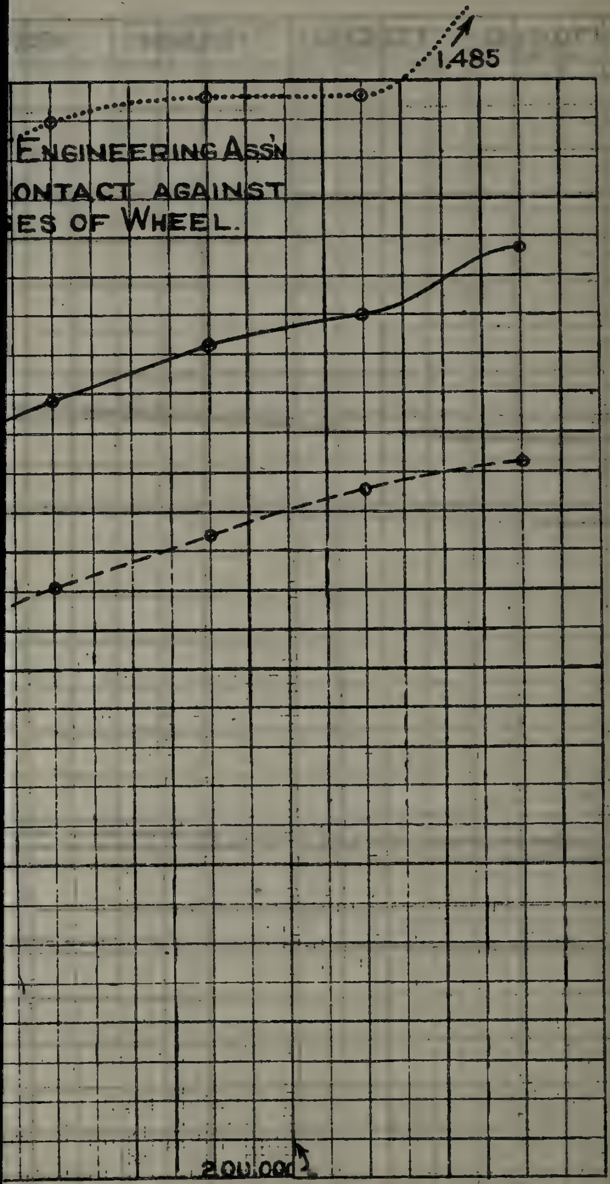
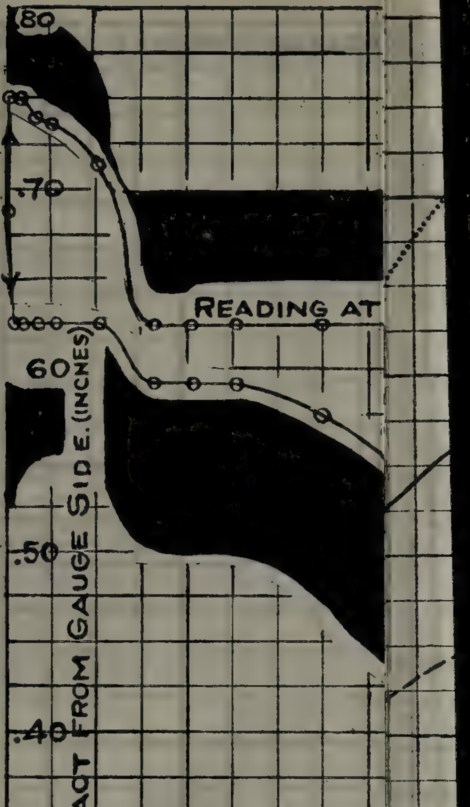


Fig. 14—Reduction in Diameter of Holes


25,000
130,000
135,000
140,000
145,000
150,000
155,000
160,000
165,000
170,000
175,000
180,000
185,000
190,000
195,000
200,000
205,000
210,000
215,000
220,000
225,000
230,000
W
S
P & O
P
O
N
M


Engineering Ass'n
ontact against
es of Wheel.
1.485
200,000


.80
.70
60
.50
.40
.30
.20
10,000
READING AT
LOCATION OF CONTACT FROM GAUGE SIDE. (INCHES)

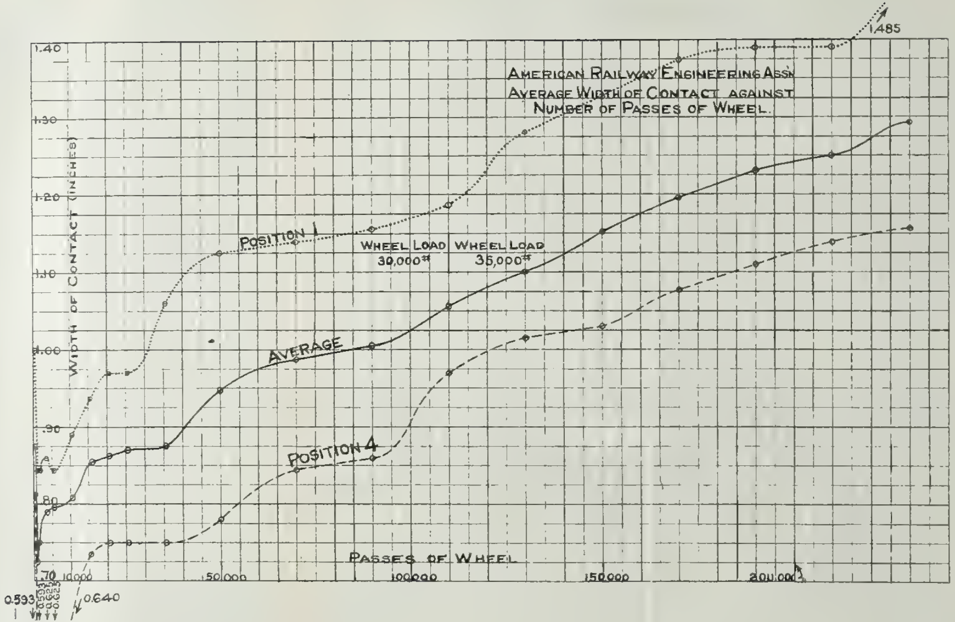


Fig. 15.—Width of Contact.

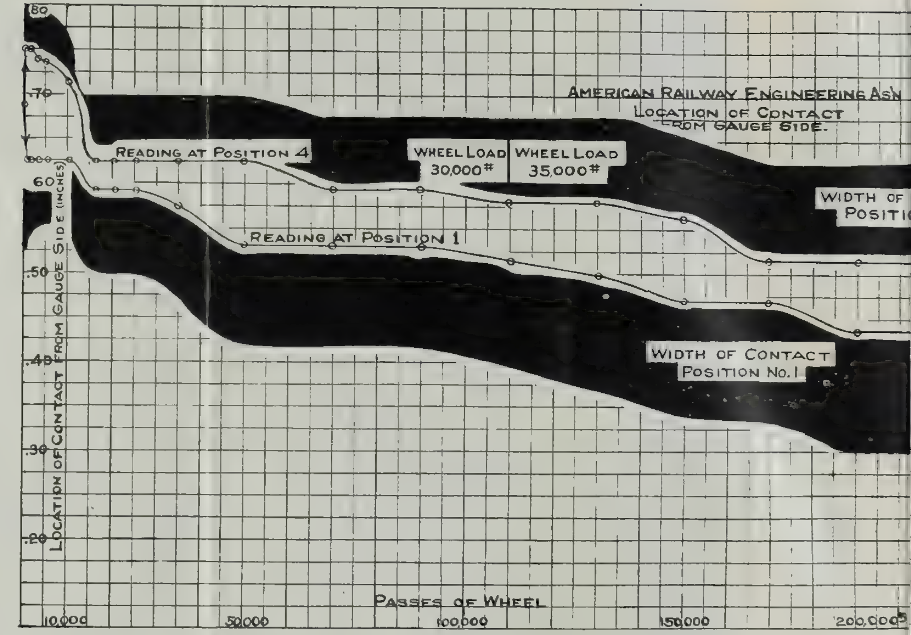


Fig 16.—Location of Contact.

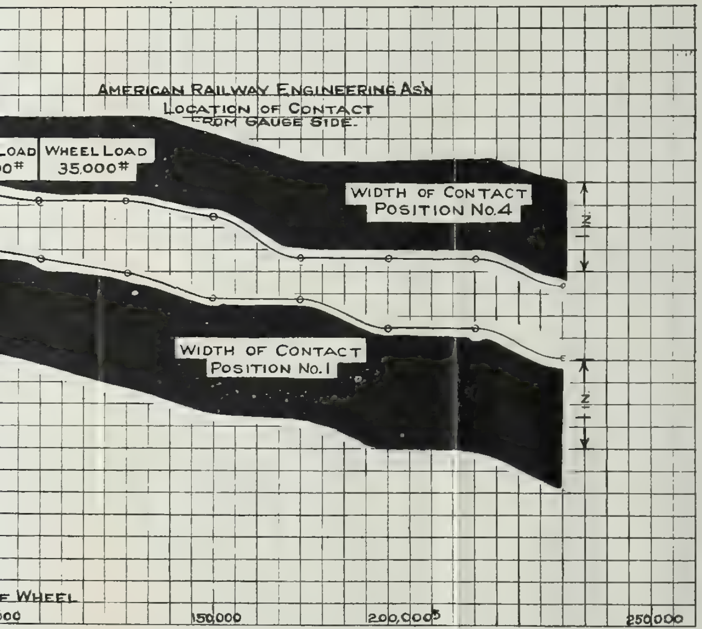


Fig 16.—Location of Contact.

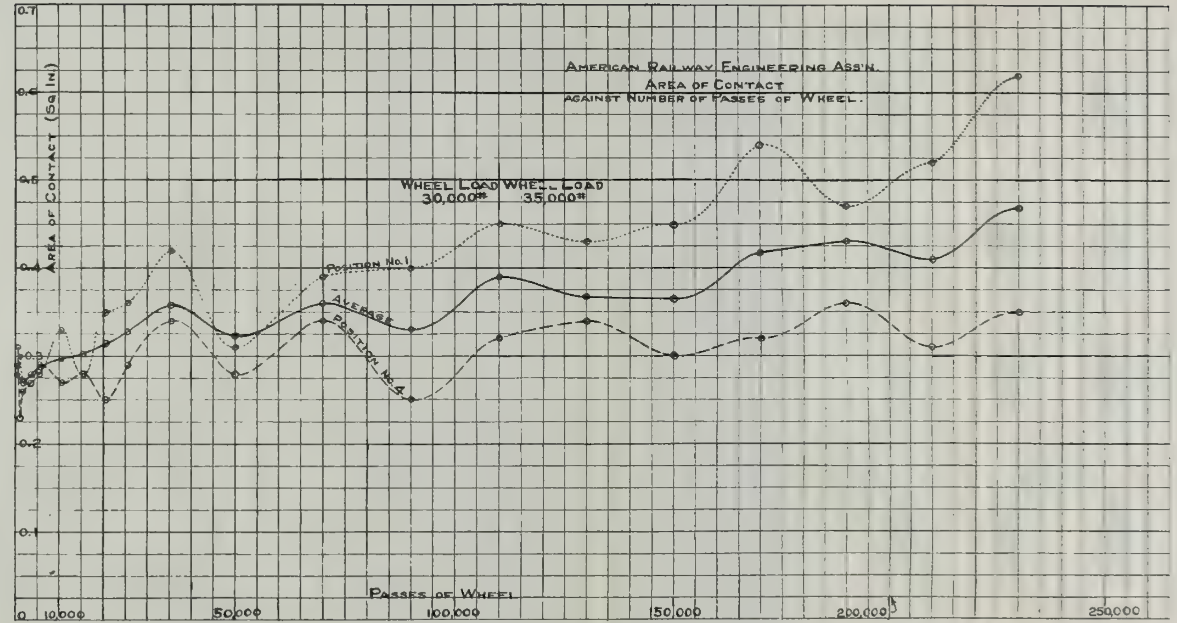
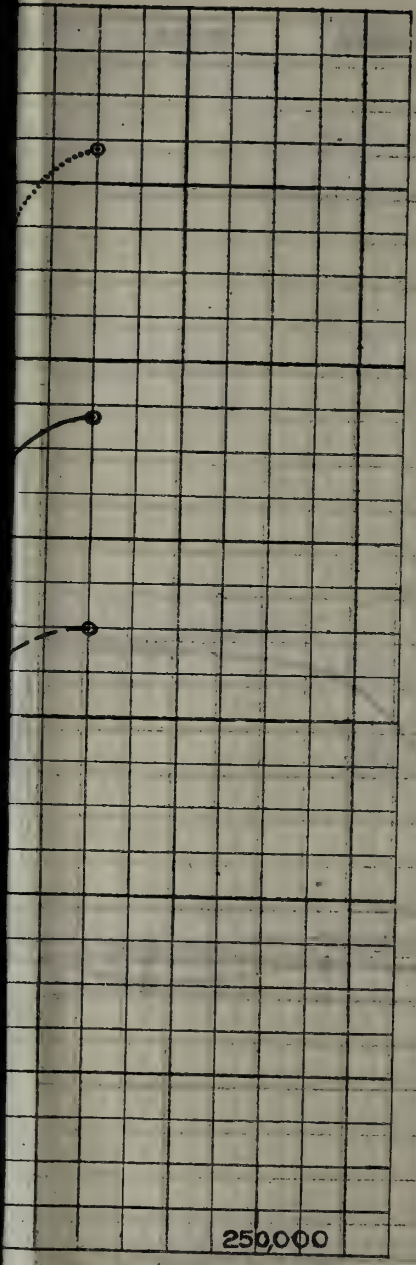


Fig. 17.—Area of Contact.



250,000

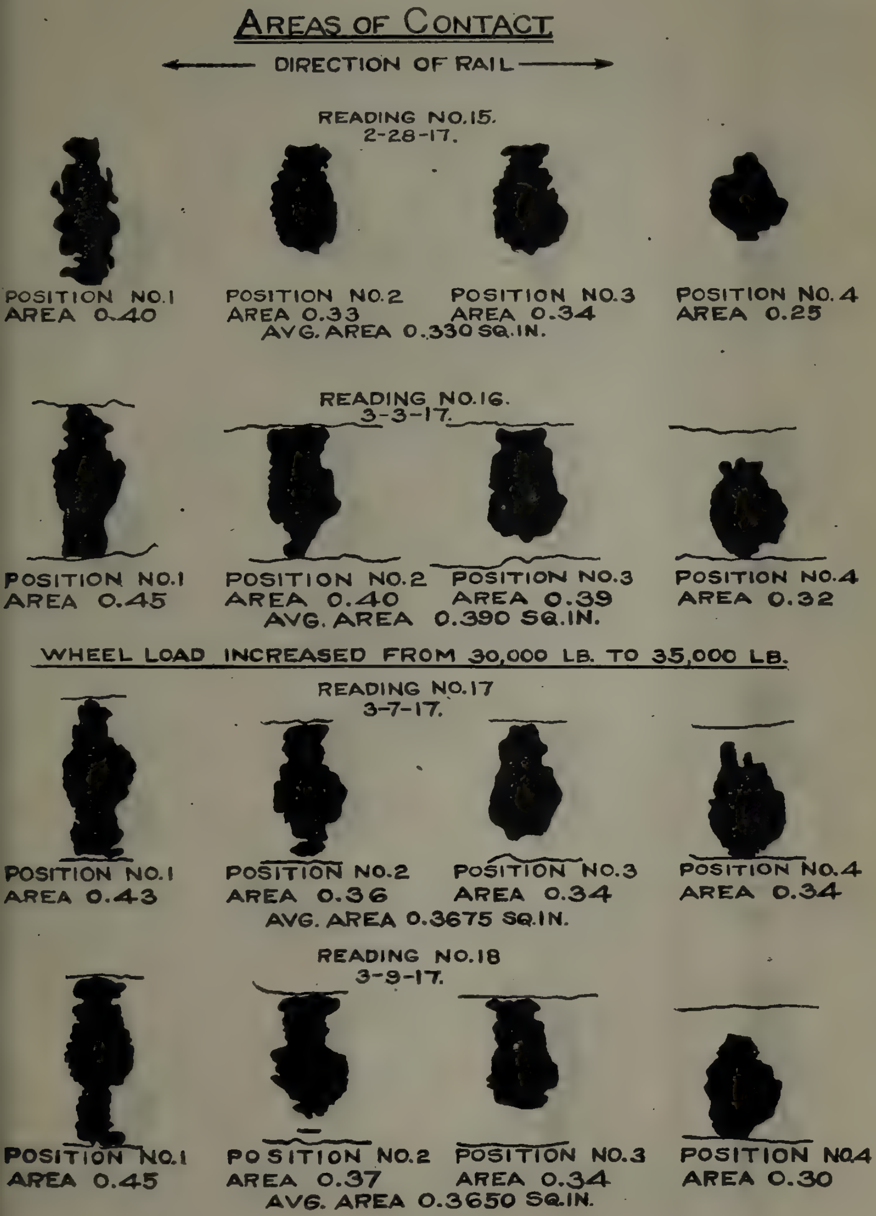


Fig. 22.

(Two-thirds Natural Size.)

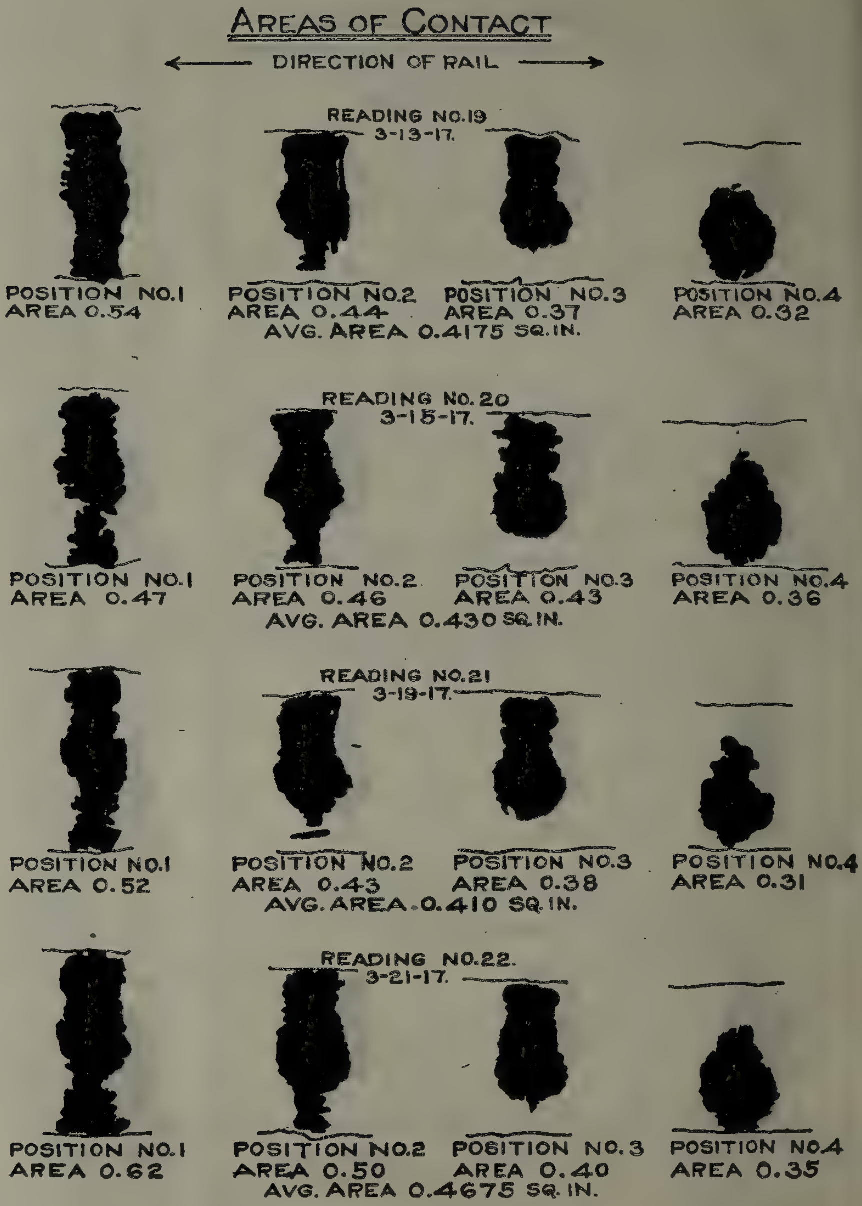


Fig. 23.

(Two-thirds Natural Size.)

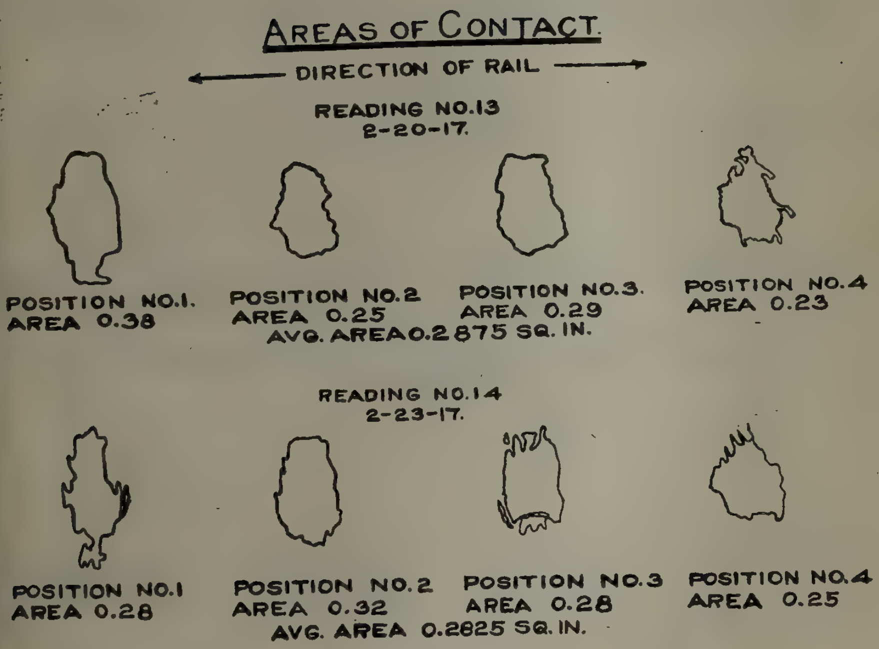


FIG. 24.

(Two-thirds Natural Size.)

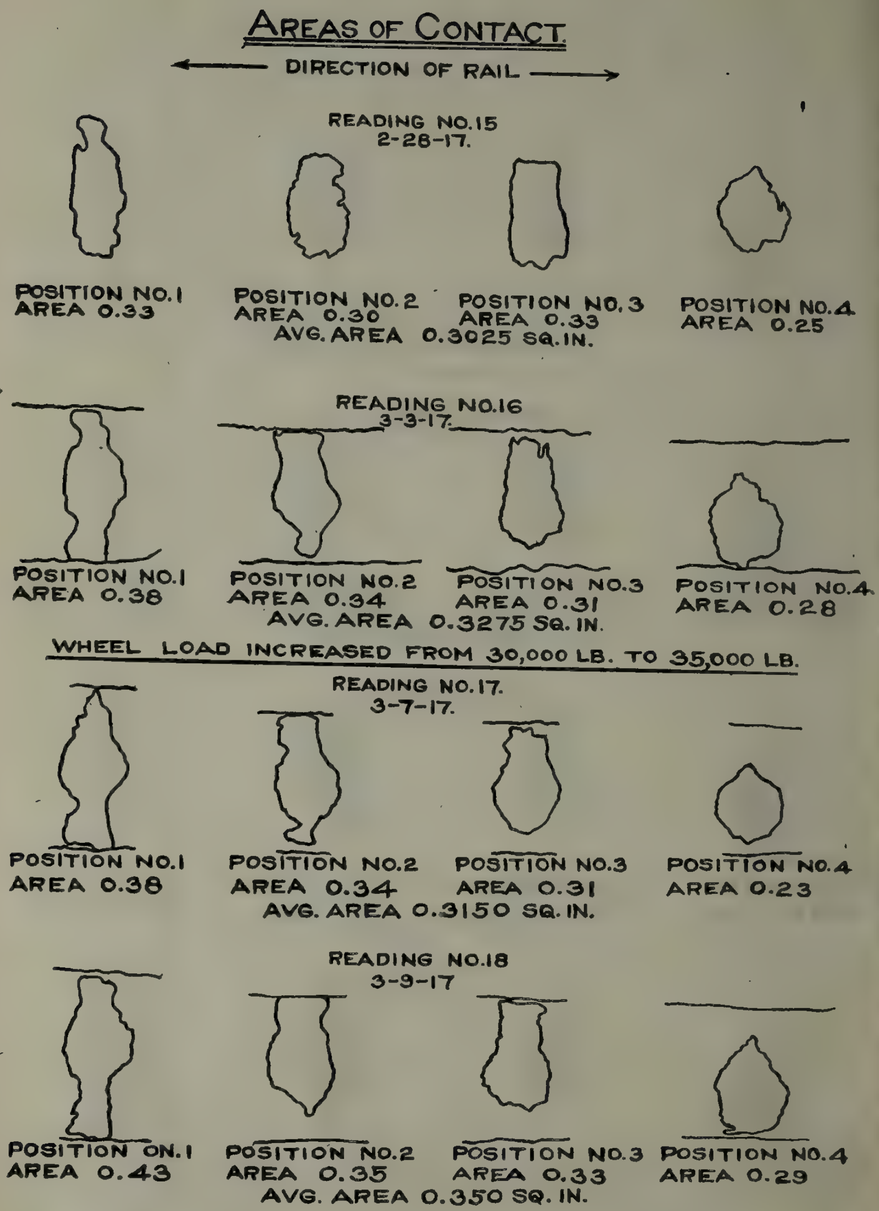


Fig. 25.

(Two-thirds Natural Size.)

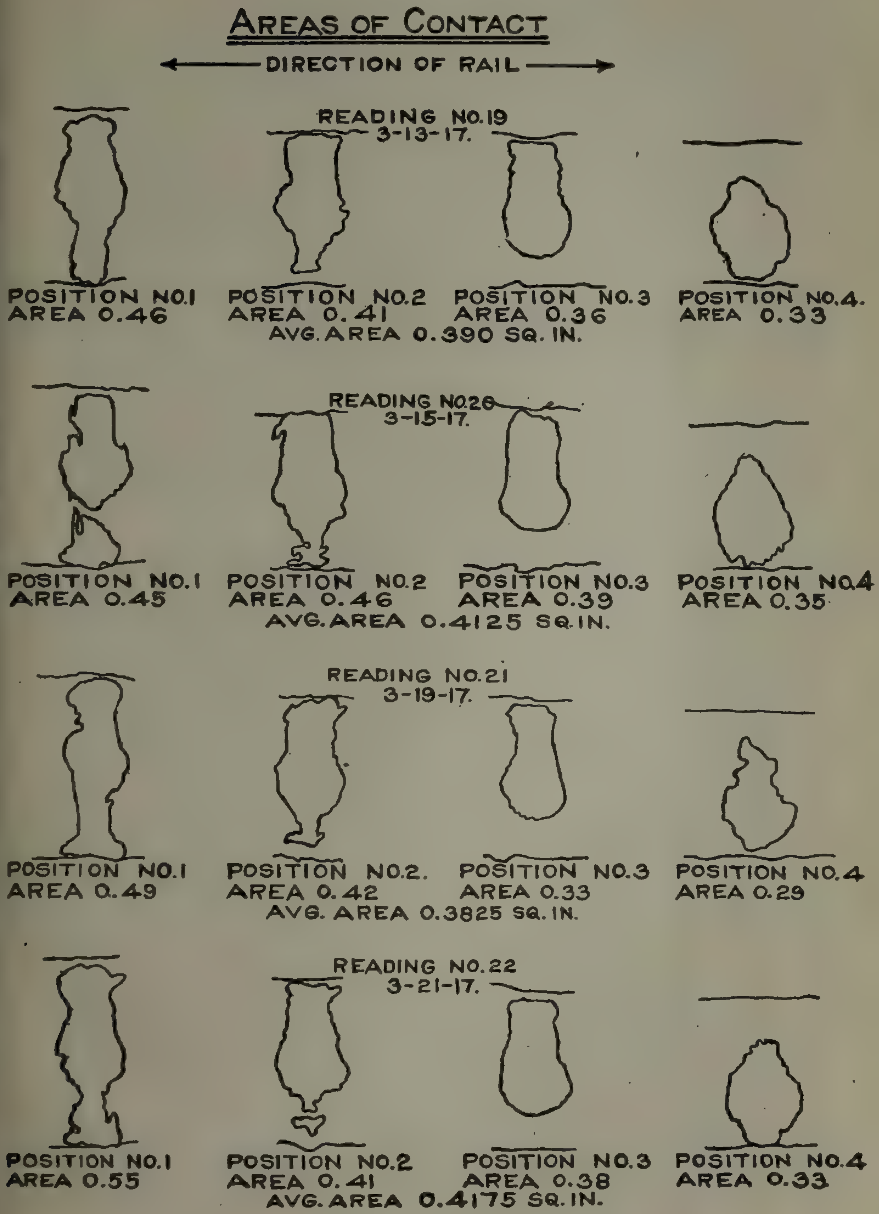


Fig. 26.

(Two-thirds Natural Size.)

PART II—FIELD TESTS.

Area of Contact Between the Rail Head and the Wheel Tread.

1. The roadbed in the right of way between terminals must be graded to provide the foundation support for the track and the wheel loads of the equipment.

2. The wheel, a tread of uniform radius, is the primary mechanism for the mobile support of itself and superimposed loads on the rails in the track. A pair of wheels are mounted per axle and two or more pairs are assembled in trucks or wheel base for the locomotives, coaches or cars.

3. The wheels roll the bearing surface of their treads lengthwise across the radius of the bearing surface of the rail heads. This forms between the metal of each to support the moving loads the pressure zones of contact, which become an area of contact, instead of a line contact, owing to the elasticity of the metal of the wheels and rails, and of both as structures.

4. Due to the principle of mobility of the wheel on the track for its own support and superimposed loads, the areas of contact must become continuous succeeding pressure zones of contact between the wheel treads and rail heads for the distance to be run.*

5. Due to the principle of configuration for the bearing surface of the rail head and the bearing surface of the wheel tread, each pressure zone of contact has a circumjacent larger zone of bending metal. This general condition is common to all of the several full contours of the rail heads and the wheel treads, but for a given load on the various radii and contours of the rail heads, does not insure or produce the same square inches in the areas of contact. Each design of rail head modifies the size of the areas of contact and average unit intensity of pressure for a given contour of wheel tread, and conversely for each contour of wheel tread on the same rail head.

6. The bending metals in the circumjacent larger zones of the areas of contact from the laws of mechanics of materials must become greater areas than the visual areas of contact to carry the wheel loads. The distribution of strains to the greater areas of metal should moderate the average unit intensity of pressure as usually computed, for the surfaces in contact are not columns, though the abrasions are limited to the areas of contact. The curves of the bending metals in the greater areas have been impressed on the copper sheets under the wheels on the rails in the track for the small areas of contact of high unit intensity of pressure.

7. The pressure zones of contact for support are formed by the radii of the rail head and wheel tread in juxtaposition, and each is reinforced by the circumjacent larger zone of metal of the same contour.

---

*Note: To study what occurs in service between the wheel treads and rail heads, rolling contacts, as well as areas of contacts, were taken on thin copper sheets.

The pressure zone contacts are neither sharp points nor knife edges, but are surfaces, which by their elasticity within the elastic limits of the steel of the rail and the wheel, can enlarge to form the areas of contact in proportion to the loads applied. This is a favorable condition of construction and action which, with well conformed contours of rail heads and wheel treads as the loads are augmented, enlarges automatically the areas of contact in like ratio. There are a number of laboratory tests on 72 and 80-inch drivers on smooth worn rails which indicate this fact for the same rail head and wheel tread, and also is confirmed nearly by Mr. Onderdonk's tests on the old rail. Such tests indicate that within the volume of elasticity of the metals, the average unit intensity of pressure—the load divided by the square inches of the area of contact—expresses an empirical constant for multiple loads on 72 to 80-inch drivers. (See Table 27.)

TABLE 27.

RESULT OF STATIC TESTS SHOWING AREAS OF CONTACT BETWEEN 72 TO 80 INCH DRIVERS FOR FOUR INCREASING LOADS AND FIVE DECREASING AREAS OF CONTACT, THOUGH IN THE LATTER A LARGER RANGE OCCURS IN SERVICE.

Load in Pounds.	*Area of Contact in Square Inches.*	*Average unit intensity of Pressure in Pounds.*
15,000	0.24	62,500
20,000	0.32	62,500
25,000	0.40	62,500
30,000	0.48	62,500
15,000	0.21	71,429
20,000	0.28	71,429
25,000	0.35	71,429
30,000	0.42	71,429
15,000	0.18	83,333
20,000	0.24	83,333
25,000	0.30	83,333
30,000	0.36	83,333
15,000	0.15	100,000
20,000	0.20	100,000
25,000	0.25	100,000
30,000	0.30	100,000
15,000	0.12	125,000
20,000	0.16	125,000
25,000	0.20	125,000
30,000	0.24	125,000

It may be possible that an empirical constant for multiple loads will be found by laboratory tests for 33-inch cast iron wheels and 36-inch steel wheels. The required accuracy for such tests is not possible under the wheel loads on the deformed rails in the track. The average unit intensity of pressure of the smaller wheels will have a higher range than those for drivers.

A high degree of accuracy must obtain in loading and measuring the areas of contact to secure within 1000 pounds above or below the probable value of each result, while the errors of the observations of each kind, should also be adjusted. New rails with the mill scale on the bearing surface of the heads as rolled, or rusty rails, should not be used for such tests as formerly was the case.

8. The pressure zones of contact, to be more easily comprehended, can be considered as momentary abutments on the rail heads and on the wheel treads to receive the running wheel loads, and transmit their strains for support to a larger foundation of metal.

9. The rolled metal layers of the supported and the circumscribed area of contact both of the rail head and the wheel tread, seem to be put in condition to exercise their greater modulus of compression—volume of elasticity—which is about three times greater than their lesser modulus of linear elasticity.

10. The rolled layers of metal $\frac{1}{32}$ to $\frac{1}{16}$ of an inch thick in the wheel treads and in the bearing surfaces of the rail heads, exercise several useful functions in and near the pressure zones of contact to sustain, modify, and distribute the wheel load effects. The rolled layer, by its increased firmness, enlarges the zone of the surface distribution of the contact strains, protects the softer metal underneath and lessens the rate of abrasion.

The rolled layer in the bearing surface of the rail head or the steel wheel tread, becomes important for service conditions. It wears down by abrasion, thickens underneath at about the same rate, and in the broad heads of good metal by tests never loses all of its ductility.

These useful functions in a general way were observed in the early service of Bessemer steel rails between the several widths of heads and radii of the bearing surface. The different interpretations of the results by railroad officials led to the establishment of two distinct systems of practice:

1. Thin broad heads of long radii.
2. Deep narrow heads of short radii.

Areas and Rolling Contacts Under Drivers and Wheels on the Track.

The areas and rolling contacts were taken on copper sheets of about 0″.0015 inch in thickness under the wheels of locomotive No. 3362, Pacific type, which had just passed through the shops; therefore the rolled layer of metal in the treads was of little thickness.

The wheels under the locomotive for the front truck and tender are 36-inch solid steel wheels. The drivers are 79 inches in diameter with steel tires 3½ inches thick. The pair of trailers are 50 inches in diameter with steel tires 3½ inches thick. The contours for all of the wheels, the inclination of the tread is 1 in 38, width 2⅜ inches, with a chamfer, ⅛-inch to the rim.

To take the areas of contact, each wheel was raised by itself, then the copper sheet was inserted between it and the rail, the wheel lowered, and again raised to remove the copper sheet with its impression.

The thin copper sheets require to be so delicate for the work that in handling them under the wheels on the rails, wrinkles occurred independent of the area of contact. Several of the static contacts had to be repeated.

Fig, 28 is a halftone reproduction of the areas and the rolling contacts. The impressions of the metal in the wheel treads due to its elasticity and that of the lower part of the wheel as a structure are convex on top, and concave on the underside, for the rail head. Steel tires of more mileage and with a firmer rolled layer in the tread, or those of cast iron wheels, do not show as much convexity.

The central depression of several of the contacts in the reproduction is due to the pressure of the glass plate under which they were held to be photographed.

The static load of construction of a given wheel is the product of the average pressure by the square inches in the area of contact inscribed on Fig. 28 for that wheel.

The pressure zone contacts produce three distinct types of the areas of contact in the track.

1. When the major axis is coincident with that of the rail, a longitudinal, oval or elliptical contact.

2. When the major axis is across the rail, a transverse oval, or elliptical contact.

3. When the axes are equal, forming a round contact, the pressure zones seem to be transformed into two spheroids.

Contours of the Rail Heads and Wheel Treads.

The contours of the rail heads and wheel treads were taken and reproduced in the relative positions they occupied in the track. The gage side of the rail head is depressed and worn below its contour, while the outside corner is built up square. (See Fig. 29.)

The rails were the New York Central former standard 6-inch, 100-lb., of Bessemer steel, rolled in 1907. The rails therefore had a worn, rolled and deformed bearing surface to distribute the wheel loads. (See Fig. 29.)

The static and rolling contacts under 33-inch cast-iron wheels were from a New York Central R. R. loaded coal car, No. 341278 (see Fig. 31). in which three show that the major axes are across the tread. (See Fig. 35.) These wheels had been in service four to seven years and the treads worn slightly hollow, which often would produce the Transverse Oval, or Elliptical type of contact, while new cast-iron wheel treads would be limited to the round type for the majority of contacts.

The contours of the rail heads and the wheel treads as taken in the track with the rolling contacts are shown in their relative position from the gage side of the head, and are reproduced in Fig. 30. The average unit intensity of pressure for one-half of the wheels figures over 100,000 pounds apiece.

Rolling Contacts Under the Wheels on the Rail Heads.

To secure the rolling contacts, the copper sheets were placed before each wheel, then the locomotive run over them and stopped, and the sheets removed. The thin copper sheets are so low in elastic limit that in the pressure zone contacts, they retain most of their impression, either of the elliptical or round form, when the wheels are raised from the rail.

Measurements for the Uniformity of Pressure in the Rolling Contacts. Some of the thin copper sheets used to obtain the areas of contact and all of the rolling contacts, have been mounted between two pieces of prepared brass and united by solder, then the pieces sawed in two or more parts, and the transverse edges polished. The technique is difficult, as would be expected, but is being mastered as skill and experience are acquired in the preparation of the mounts.

The minute pits in the steel of the rail head or the wheel tread may be partially filled with copper, but unless continuous, become distinct protuberances, and need not be included in measurements by a Filar micrometer. These protuberances, as well as scale, rust or dust from either the wheel tread or the rail head, are included by the ordinary contact micrometer, and therefore cannot be used.

The measurements of the copper mounts have been made under the Filar micrometer on the microscope stand designed by Dr. Dudley to be free from tremors, and had especially constructed to measure the unit strains in the base of rails under moving trains, autographically recorded by his Stremmatograph on phosphor bronze slides. One space of the micrometer head reads to one micron, and a reading to one-half space or less, is usually possible. The reduction of the measurements often carries them out to 0.00001 of an inch for comparison, but the last decimal is only the nearest approximation. The areas and rolling contacts on the thin copper sheets under steel wheels and tires show a little more intensity of pressure near the center of the contact by the greater reduction in thickness of the copper, though the measurements are more uniform over a central area than generally expected, particularly the 79-inch drivers. The contacts under new cast iron wheels show the greatest intensity of pressure at and around the center of the contact, while worn cast iron wheels show more favorable types of contacts.

The static areas of contact taken upon the rail in the track under the wheel treads, the major axis is generally lengthwise of the rail except for some of the 33-inch cast iron wheels which were worn slightly hollow in the tread. The ellipses are oval or pointed whether the major axis is longitudinal or transverse. The contacts on the Sparrows Point machine show the major axes are across the head of the rail, which would be the case with only one wheel passing forward and backward on the same rail. This differs from track conditions by the same wheel and rail being used for the wear of the successive areas of contact. The ellipses are not as oval or pointed in the major axes as those taken on the track.

The wheel treads of service are shaped by thousands of rails, some partly worn and others nearly ready to be removed from the track, while the contour of the rail head is also worn by thousands of wheels, and service conditions should be studied to maintain or improve them.

The rolling contacts measure wider under the Filar micrometer than the estimate of the visual contact, for the reason that traces of the circumjacent zone are included and the gradual reduction in thickness of the copper sheet is more readily found under magnification than by the eye. The mounts are measured on the stage to each one-half millimeter of length.

The measurements of the thickness of the copper sheets placed under wheels of railroad equipment are the first ever made so far as we know, either for static or rolling contacts on rail heads, and the technique for the research had to be developed.

The results indicate the favorable relations which do and can exist between the wheel treads and rail heads much better than words can express, therefore are of practical and scientific value.

The tables of the measurements of the rolling contacts at right angles to the rail lengths, differ in size per wheel, as would be expected from a study of the forms and fractions of a square inch in the different types of the areas of contact in Fig. 28, and their plotted illustrations in Fig. 32.

Some of the variations per wheel are due to the treads just turned in the shop before they had worn smooth over their width excluding the chamfer. The major portion of the variations are due to the worn and deformed bearing surface of the rail heads in combination with the important factor that the two wheels on the same axle are mounted with three-fourths of an inch play between the flange and that of the gage of the track.

One flange may be near the rail head while the opposite wheel on the same axle must be off and the two contacts are not equally centered over the rail head. The curve of the wheel tread and the curve of the rail head, which between them form the point of osculation for contact and support, may be on opposite sides of the tangent common to both curves and produce the type of area of contact of a small longitudinal oval. (See Fig. 33.)

The opposite wheel tread with flange off from the rail head, its curve and that of the rail head, which between them form the point of osculation, may be on the same side of the common tangent of both and produce either the type of area of contact of a large longitudinal oval or transverse oval. (See Fig. 34.)

The wheel tread and the rail head separated by the thin copper sheets, rendered possible the impressions of the bending metals in the circumjacent larger zone of the area of contact. The impressions were disclosed by the measurements of the copper sheets for Tables L and H, and indicated on one side or both in several others, and confirm the fact which we considered and stated as a theory from the Laws of Mechanics of Materials in Sections 5 and 6. This makes the diagram of the plotted Table L interesting and instructive.

It was not expected to obtain in the track indications as complete as these where dust and scale on the wheel treads and rail heads often are abundant and contacts of uniform pressure on the worn and deformed bearing surface of the rail heads are so difficult to secure.

The deformed rail heads are those in which the metal of the bearing surface is depressed and worn on the gage side below its proper contour, yet the outside corner builds up square from the great variety of the wheel contours. This concentrates the wheel loads on a narrow bearing surface of one-fourth to one-half of an inch in width on the head between the gage side and the center of the head. The unit stresses in the base of the rail are often larger in the outside flange than in the inner flange.

The rail heads which are worn uniformly over the entire contour of the head are uninjured, while the wheel load pressures are distributed to nearly an inch or more in width of the bearing surface, therefore to a greater mass of metal with less average unit intensity of pressure. The unit stress in both flanges of the base of the rail is more nearly uniform under this favorable loading.

The curves have been plotted from the respective tables on the assumption of an equal reduction of the thickness of the copper sheets above and below the median line of the illustration. The upper and lower surfaces of the figure by this method show in the measured line of the rolling contacts the outline of the reduced thickness of the copper in hundred-thousandths of an inch, indicating the uniformity of pressure to carry and support the wheel loads. It may be possible in the future to assign to each metal of the wheel tread and rail head its portion of contributed elasticity.

The median line in the area of contact of the illustration is used to represent approximately the metal surfaces of the pressure zones of contact of the wheel tread and the rail head, which form the area of contact due to their elasticity. This represents only a part of the elasticity of the metals of the wheel tread and rail head and their structures exercised to support the wheel loads.

To help the mind grasp the minute reduction of the copper sheets to carry the wheel loads, the illustration of the plotted Table L will be used for an explanation. This was a small longitudinal oval 0.14 square inches of the area of contact, the major axis was one-half inch long and the minor axis three-eighths of an inch wide. The minor axis of the circumjacent zone of bending metals—including that of the area of contact—is seven times wider than the original, but the minor axis of the area of contact, eight times. The draughtsman's median line of the illustration is five hundred and four hundred-thousandths (0".00504) of an inch thick, thirty-six times the fourteen hundred-thousandths of an inch (0".00014), for the measured reduced thickness of the copper sheet at the center of the contact to carry the wheel load as plotted in the scale for the illustrations.

We are dealing in these measurements with smaller fractions of an inch than can be measured by ordinary micrometers and between the pressure zones of contact of the wheel tread and rail head, one hundred-thousandth of an inch (0".00001) is divided several times.

The plotted curves on such a large scale will often appear irregular from dust or scale on the wheel tread or rail head which cannot be avoided in a track which is but one of a series of tracks with trains passing nearly every minute.

Table A is given herewith as a sample of the numerous tables of measurements from which the graphics were made.

SAMPLE TABLE A.

Measurements of the Thickness of the Copper Sheet for Rolling Contact.
Cast Iron Wheel, R. 1-B, Coal Car No. 341278, Date, 1-15-18.
Type of Area of Contact, Round. 0.16 Sq. Inches.

Remarks	Stage Position in mms.	Micrometer Readings		Reduction in Thickness From Normal
		Microns	Reduced to Decimals of an Inch	
Left of Contact	17.0	38.0	0".00152	0".00000
Left of Contact	17.5	38.0	0".00152	0".00000
Left of Contact	18.0	38.0	0".00152	0".00000
Left of Contact	18.5	38.0	0".00152	0".00000
Edge of Contact	19.0	36.0	0".00144	0".00008
In Contact	19.5	35.5	0".00142	0".00010
In Contact	20.0	35.5	0".00142	0".00010
In Contact	20.5	35.0	0".00140	0".00012
In Contact	21.0	35.0	0".00140	0".00012
In Contact	21.5	35.0	0".00140	0".00012
In Contact	22.0	35.0	0".00140	0".00012
In Contact	22.5	35.0	0".00140	0".00012
In Contact	23.0	34.5	0".00138	0".00014
In Contact	23.5	34.5	0".00138	0".00014
In Contact	24.0	34.5	0".00138	0".00014
In Contact	24.5	34.5	0".00138	0".00014
In Contact	25.0	35.5	0".00142	0".00010
In Contact	25.5	35.5	0".00142	0".00010
In Contact	26.0	35.5	0".00142	0".00010
In Contact	26.5	35.5	0".00142	0".00010
In Contact	27.0	35.5	0".00142	0".00010
In Contact	27.5	35.5	0".00142	0".00010
In Contact	28.0	35.5	0".00142	0".00010
In Contact	28.5	35.5	0".00142	0".00010
In Contact	29.0	35.5	0".00142	0".00010
In Contact	29.5	35.5	0".00142	0".00010
In Contact	30.0	36.5	0".00146	0".00006
In Contact	30.5	37.5	0".00150	0".00002
Edge of Contact	31.0	38.0	0".00152	0".00000
Edge of Contact	31.5	38.0	0".00152	0".00000
Edge of Contact	32.0	38.0	0".00152	0".00000
Edge of Contact	32.5	38.0	0".00152	0".00000

Note.—Copper sheet somewhat rough due to irregularities in the wheel tread, 0.1 to 0.2 of mm. in length.

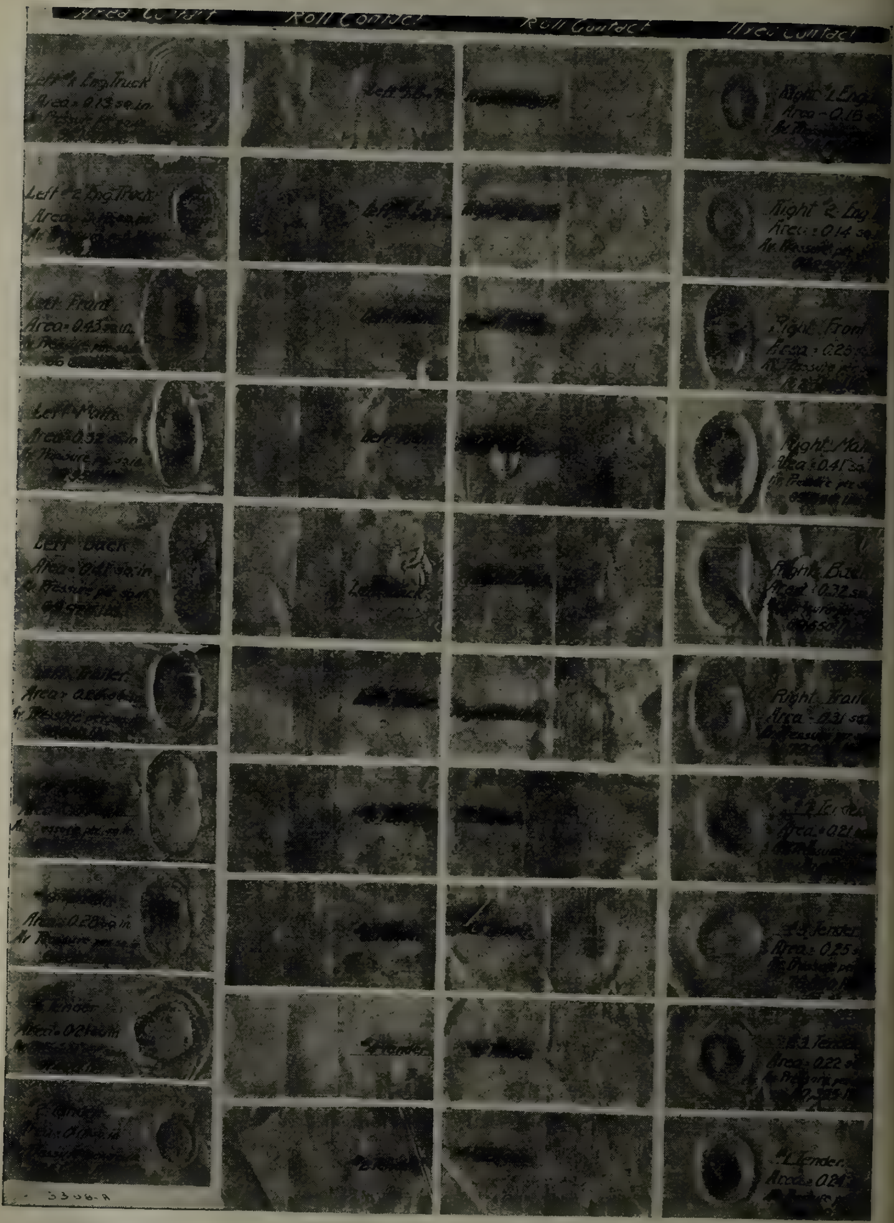


FIG. 28.—AREAS AND ROLLING CONTACTS OF LOCOMOTIVE AND TENDER WHEELS.

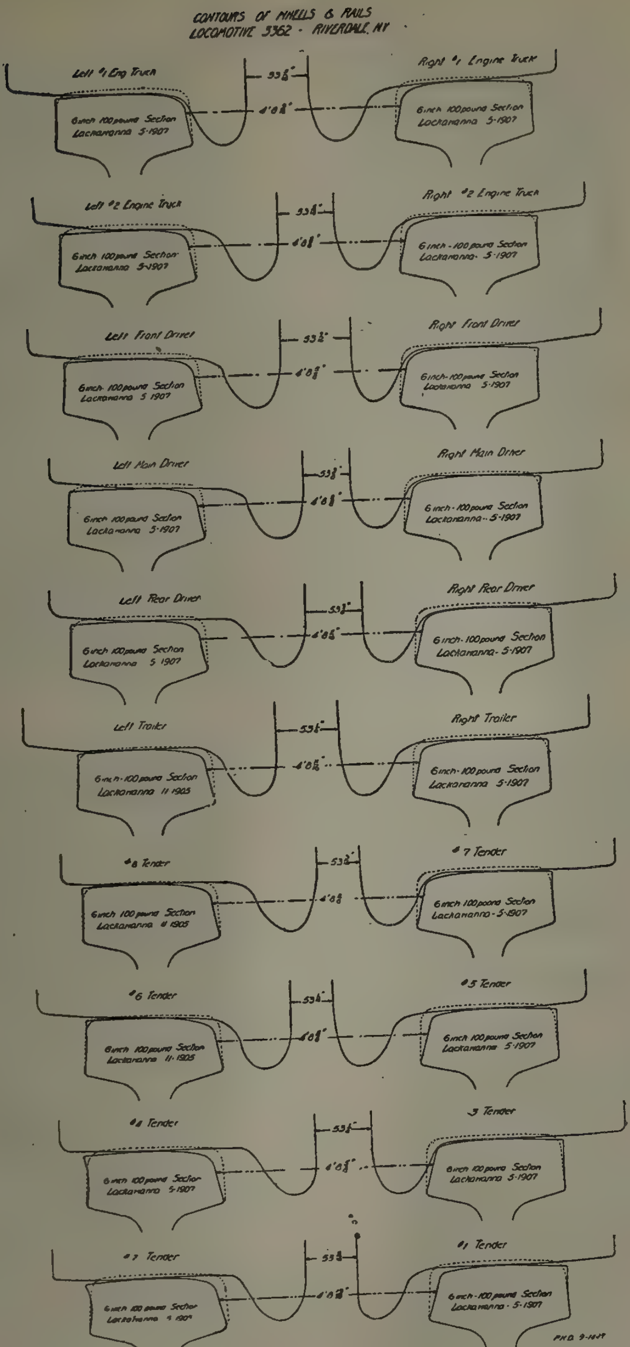


FIG. 29.—CONTOURS OF RAILS AND WHEELS, LOCOMOTIVE 3362.

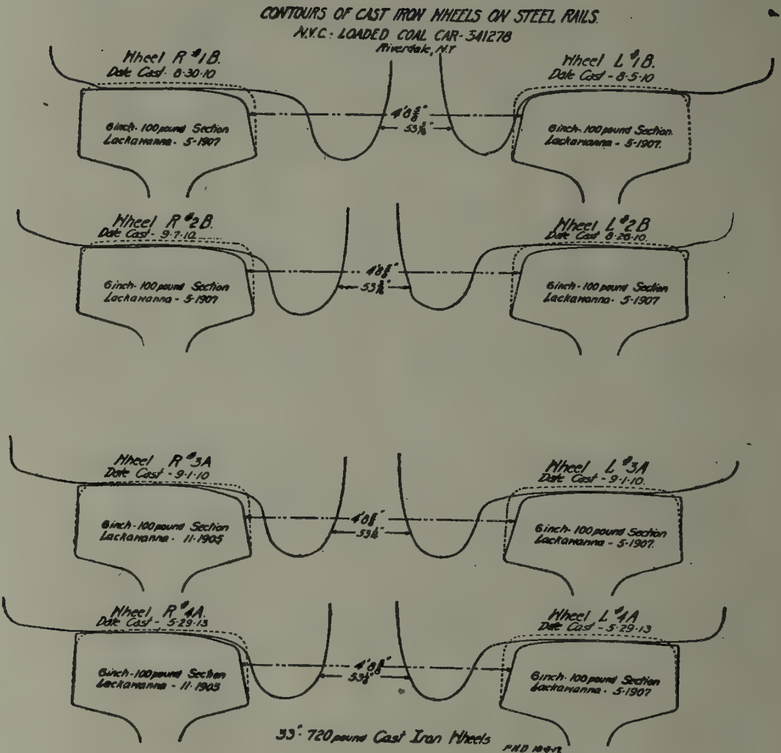


FIG. 30.—CONTOURS OF RAILS AND WHEELS, CAR 341278.

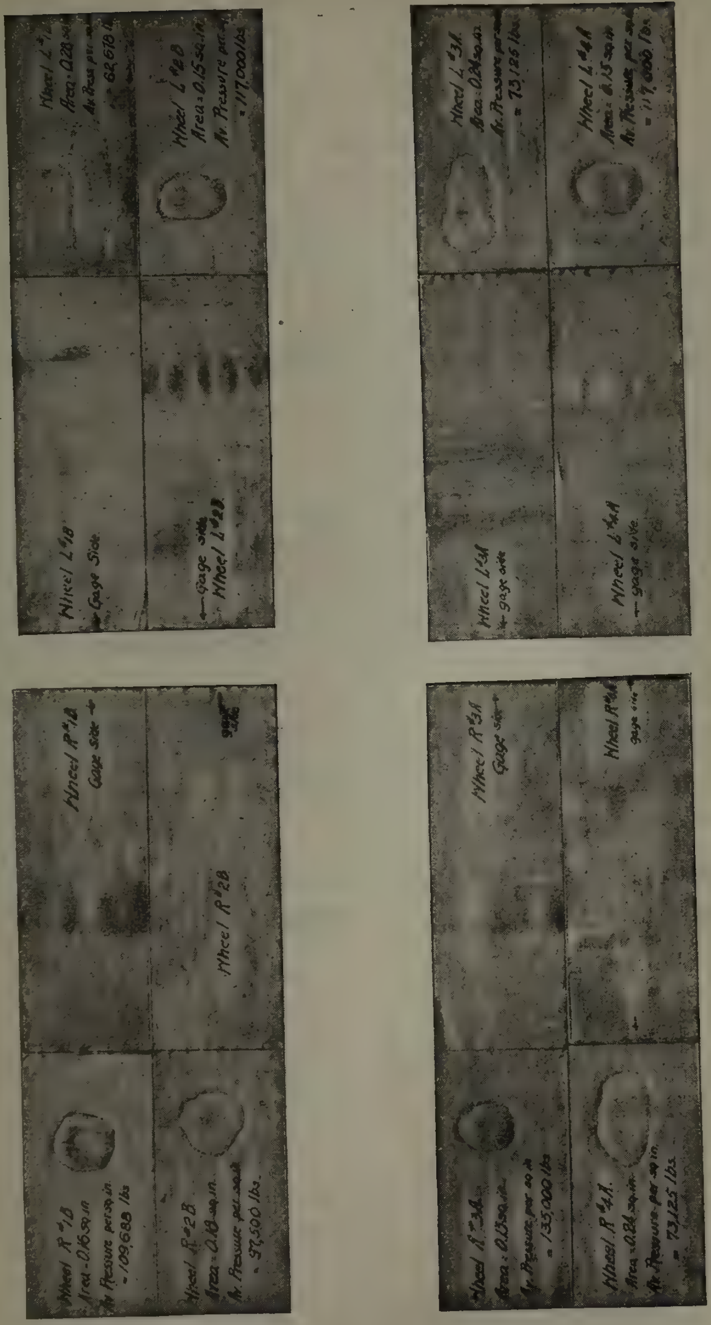


FIG. 31.—AREAS AND ROLLING CONTACTS OF 33-INCH CAST-IRON CAR WHEELS.

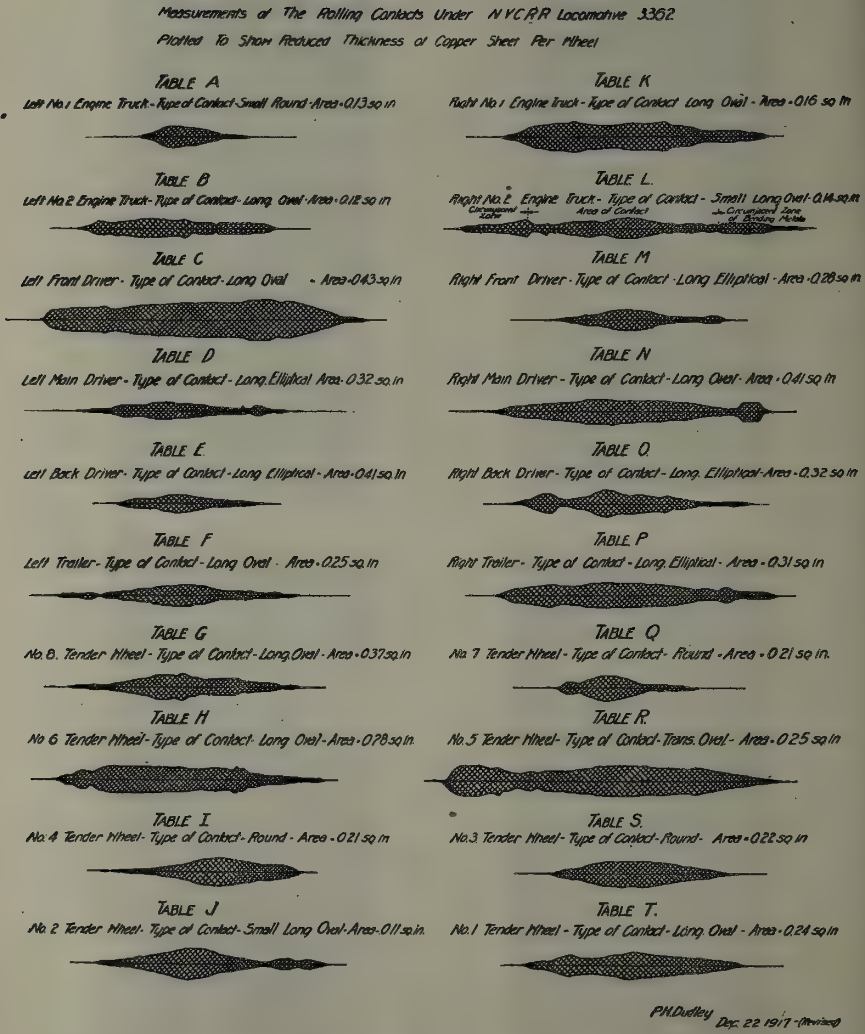
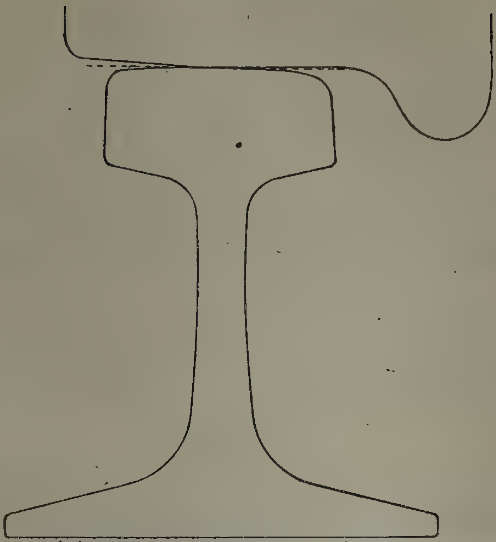
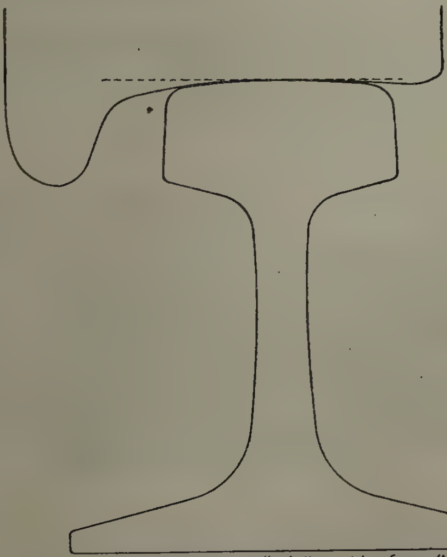

Measurements of The Rolling Contacts Under N.Y.C.R.R. Locomotive 3362
Plotted To Show Reduced Thickness of Copper Sheet Per Wheel
TABLE A
Left No. 1 Engine Truck - Type of Contact - Small Round - Area - 0.13 sq. in
TABLE B
Left No. 2 Engine Truck - Type of Contact - Long Oval - Area - 0.12 sq. in
TABLE C
Left Front Driver - Type of Contact - Long Oval - Area - 0.43 sq. in
TABLE D
Left Main Driver - Type of Contact - Long Elliptical Area - 0.32 sq. in
TABLE E.
Left Back Driver - Type of Contact - Long Elliptical - Area - 0.41 sq. in
TABLE F
Left Trailer - Type of Contact - Long Oval - Area - 0.25 sq. in
TABLE G
No. 8. Tender Wheel - Type of Contact - Long Oval - Area - 0.37 sq. in
TABLE H
No 6 Tender Wheel - Type of Contact - Long Oval - Area - 0.78 sq. in.
TABLE I
No. 4 Tender Wheel - Type of Contact - Round - Area - 0.21 sq. in
TABLE J
No. 2 Tender Wheel - Type of Contact - Small Long Oval - Area - 0.11 sq. in.
TABLE K
Right No. 1 Engine Truck - Type of Contact Long Oval - Area - 0.16 sq. in
TABLE L.
Right No. 2 Engine Truck - Type of Contact - Small Long Oval - 0.14 sq. in
Circumjacent Zone
Area of Contact
Circumjacent Zone of Bonding Metals
TABLE M
Right Front Driver - Type of Contact - Long Elliptical - Area - 0.28 sq. in
TABLE N
Right Main Driver - Type of Contact - Long Oval - Area - 0.41 sq. in
TABLE O.
Right Back Driver - Type of Contact - Long. Elliptical - Area - 0.32 sq. in
TABLE P
Right Trailer - Type of Contact - Long. Elliptical - Area - 0.31 sq. in
TABLE Q
No. 7 Tender Wheel - Type of Contact - Round - Area - 0.21 sq. in.
TABLE R.
No. 5 Tender Wheel - Type of Contact - Trans. Oval - Area - 0.25 sq. in
TABLE S.
No. 3 Tender Wheel - Type of Contact - Round - Area - 0.22 sq. in
TABLE T.
No. 1 Tender Wheel - Type of Contact - Long. Oval - Area - 0.24 sq. in
P.H. Dudley Dec. 22 1917 - (Revised)

FIG. 32.—REDUCTION OF THICKNESS OF COPPER SHEETS IN ROLLING CONTACTS, LOCOMOTIVE 3362.



A standard tread which forms the point of osculation between the wheel tread and rail head with the common tangent between the surfaces in contact

FIG. 33.—DIAGRAM SHOWING POINT OF OSCULATION OF RAIL AND WHEEL.



A tread worn slightly hollow which forms the point of osculation between the wheel tread and rail head below. the common tangent of both.

FIG. 34.—DIAGRAM SHOWING POINT OF OSCULATION OF RAIL AND WHEEL.

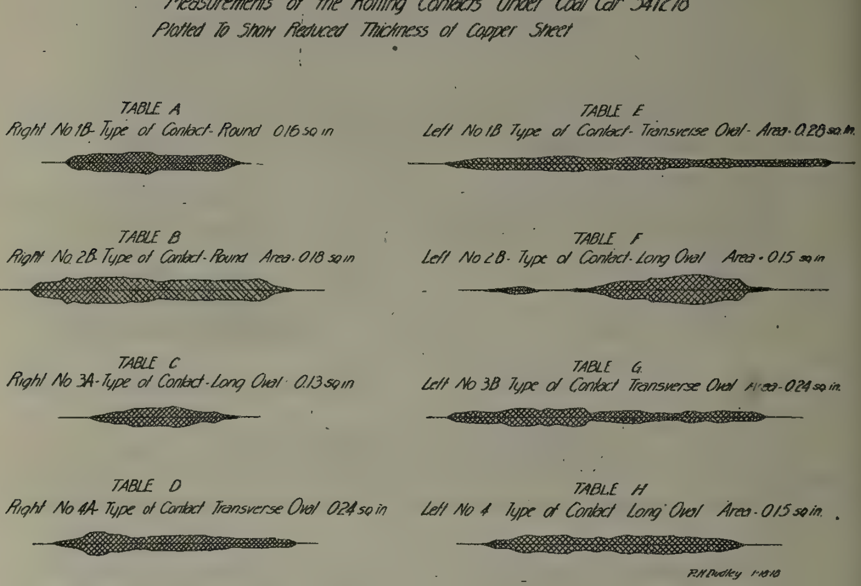


FIG. 35.—REDUCTION OF THICKNESS OF COPPER SHEETS IN ROLLING CONTACTS, CAR 341278.

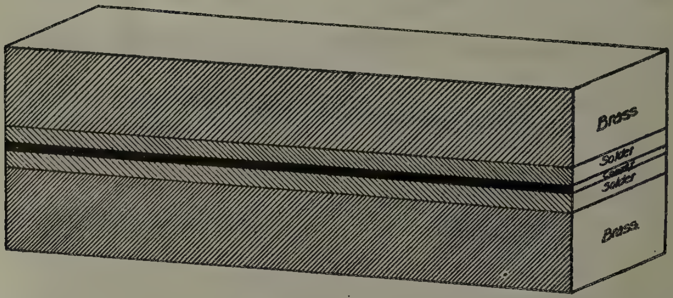


FIG. 36.—SHOWING THE METHOD OF MOUNTING THE COPPER STRIPS OF THE AREA OF CONTACT OR ROLLING CONTACTS BETWEEN THE TWO PIECES OF BRASS IN WHICH ALL OF THE SURFACES ARE UNITED BY A MATRIX OF SOLDER.

BULLETIN

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REPORT OF COMMITTEE XVIII—ON ELECTRICITY.

EDWIN B. KATTE, *Chairman;*	A. G. SHAVER, *Vice-Chairman;*
A. H. ARMSTRONG,	GEORGE W. KITTREDGE,
H. M. BASSETT,	C. E. LINDSAY,
Z. M. BRIGGS,	W. L. MORSE,
D. J. BRUMLEY,	W. S. MURRAY,
R. D. COOMBS,	J. A. PEABODY,
A. O. CUNNINGHAM,	FRANK RHEA,
WALT DENNIS,	J. R. SAVAGE,
R. H. FORD,	M. SCHREIBER,
W. F. GRAVES,	H. U. WALLACE,

Committee.

To the American Railway Engineering Association:

Your Committee presents herewith its report for the year 1917.

The following outline of work was assigned to this Committee by the Board of Direction:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes.
2. Keep up to date all statistical data relative to clearances of third rail and overhead structures.
3. Report on the study of electrolysis and insulation and its effect on reinforced concrete structures.
4. Report on study of maintenance organization, and relation to track structures.
5. Report on proper type of overhead catenary construction, with particular reference to the consideration of providing clear vision for signals, co-operating with the Committee on Signals and Interlocking.
6. Report on utilization of water power for electrical railway operation, in collaboration with the Committee on Conservation of Natural Resources.
7. Report recommended practice for eliminating, as far as practicable, the interference with telephone and telegraph lines caused by the use of propulsion circuits.
8. Report on the interference with telegraph and telephone circuits, caused by the use of a direct current propulsion circuit and methods of eliminating this effect as far as is practicable.
9. Continue co-operation with the National Joint Committee on Electrolysis and the National Joint Committee on Overhead and Underground Line Construction.
10. Study and make report on any desirable changes in the National Electrical Safety Code issued by the Bureau of Standards.

COMMITTEE MEETINGS.

Three meetings were held during the year, as follows:

The first meeting was held at Niagara Falls, August 17th, 1917, the following members being present:

Edwin B. Katte, Chairman; H. M. Bassett, Z. M. Briggs, D. J. Brumley, R. H. Ford, Walt Dennis, C. E. Lindsay, W. L. Morse, J. R. Savage, M. Schreiber.

At this meeting, sub-committees were appointed and the work for the year outlined.

The second meeting was held in Buffalo, N. Y., December 12th, 1917, the following members being present:

Edwin B. Katte, Chairman; A. H. Armstrong, W. L. Morse, M. Schreiber.

This meeting was preceded by a heavy snowstorm which prevented many members of the Committee from attending. The work of the day consisted in a review of the reports of Sub-Committees on Electrical Definitions, Third Rail and Overhead Clearances, Electrolysis and Insulation, and Water Power.

The third meeting was held in New York City, December 20, 1917, the following members being present:

Edwin B. Katte, Chairman; A. H. Armstrong, H. M. Bassett, R. H. Ford, George W. Kittredge, W. L. Morse, M. Schreiber, L. S. Wells, representing J. R. Savage.

At this meeting the reports of the sub-committees were read, revised and ordered submitted to the Association, as follows:

(ITEM 1) REVISION OF MANUAL.

SUB-COMMITTEE NO. 1.

A. H. Armstrong, *Chairman;*
R. D. Coombs,
George W. Kittredge,
C. E. Lindsay,
W. F. Graves.

The following definitions are submitted for publication in the Proceedings with a view of their final adoption for the Manual after a year's trial. These definitions, so far as possible, conform with those adopted by the U. S. Bureau of Standards, printed in the National Electrical Safety Code, and those of the American Institute of Electrical Engineers. It is recommended that the definitions be adopted tentatively, with the understanding that they will be reconsidered in the light of suggestions which may be received during the coming year.

It will be noted that the definitions are arranged in alphabetical order, rather than in logical sequence. This has been done with a view of conforming to the common usage in the Manual. Words in parenthesis after each definition indicate new definitions by the word "proposed" or the source of existing definitions.

Electrical Definitions.

Bond.—A metallic means for connecting two rails to permit of passage of electric current. (A. R. E. A. Manual.)

Bonder.—An employe qualified to install or maintain bonds and their appurtenances. (Proposed.)

Bracket Support.—An arm supporting the trolley wire or catenary. (Proposed.)

Bridge Support.—A rigid overhead structure upheld at each end, supporting the trolley wire or catenary. (Proposed.)

Cable.—Wires bound together, acting as a conductor. (Proposed.)

Catenary Suspension.—All forms of overhead trolley construction in which the trolley wires are attached to one or more supporting cables, which in turn are attached to the main supporting system. (Proposed.)

Clearance Line (Equipment).—Lines beyond which no part of the equipment shall project. Allowance must be made by equipment manufacturers for new equipment for wear on journals and brasses on axle collars, on rails, on wheels, compression of springs, sagging of center of car, constructional variations, end play, broken springs, etc. (A. R. E. A. Manual.)

Clearance Line (Third Rail).—Lines beyond which no part of the third rail structure shall project. (A. R. E. A. Manual.)

Conductor.—A continuous metallic path for the flow of electricity. (Proposed.)

Contact Conductor.—That part of the distribution system other than the traffic rails which is in immediate electrical contact with the circuits of the cars or locomotives. (A. I. E. E. 706.)

Contact Rail.—A rigid contact conductor. (A. I. E. E. 767.)

Contact Rail (Overhead).—A contact rail above the elevation of the maximum equipment line. (A. I. E. E. 768.)

Cross Span Support.—Flexible overhead wires or cables upheld at each end, supporting the trolley wire or catenary. (Proposed.)

Direct Suspension.—All forms of overhead trolley construction in which the trolley wires are attached by insulating devices directly to the main supporting system. (A. I. E. E. 780.)

Distribution System.—That portion of the conductor system which carries current of the kind and voltage received by the cars or locomotives. (Proposed.)

Duct Line.—A structure consisting of one or more pipes laid up in banks in which may be placed wires or cables. (Proposed.)

Electrical Supervisor.—An official of the division staff, qualified to supervise the maintenance of the electrical transmission and working conductors, outside of the power stations and sub-stations. (A. R. E. A. Manual.)

Jumper.—A cable used to connect the ends of two contact conductors. (A. R. E. A., Vol. 18, page 145.)

Patrolmen.—Employes qualified to inspect and make minor repairs to track and third-rail structure, cables and wires, and to use hand signals for the protection of trains. (A. R. E. A. Manual.)

Pulling Chamber.—A chamber similar to but smaller than the splicing chamber, and used primarily for pulling cables and wires into ducts. (A. R. E. A., Vol. 18, page 145.)

Splicing Chamber.—A chamber in a duct line where cables are spliced and inspected. (A. R. E. A., Vol. 18, page 144.)

Sub-Station.—A group of apparatus or machinery which receives current from a transmission system, changes its kind or voltage and delivers it to a distribution system. (A. I. E. E. 762.)

Third Rail.—A contact conductor placed at either side of the track, the contact surface of which is a few inches above the level of the top of the track rails. (A. I. E. E. 769.)

Third Rail Gage.—Distance measured parallel to plane of top of both running rails between gage of nearest running rail and inside gage line of third rail. (A. R. E. A. Manual.)

Traction Linemen.—Employes qualified to maintain wires and cables and their appurtenances for all railroad voltages. (A. R. E. A. Manual.)

Transmission System.—That portion of the conductor system carrying current of a kind or voltage different from that received by the cars or locomotives. (Proposed.)

Transmission Line.—A system of towers or poles and cables or wires carrying current from the source of power to the sub-stations. (Proposed.)

Trolley Wire.—A flexible contact conductor customarily supported above the cars. (A. I. E. E. 777.)

(ITEM 2) CLEARANCES—THIRD-RAIL AND OVERHEAD.

SUB-COMMITTEE NO. 2.

H. M. Bassett, *Chairman;*	W. F. Graves,
A. O. Cunningham,	J. A. Peabody.
A. G. Shaver,	

The Committee has during the past year communicated with officers of railroads operating electrically, either by third rail or overhead conductors. No radical changes have been adopted with the exception of broadening the number of inquiries and the replies cover a larger number of railroads this year than formerly.

Tabular statement No. 1, page 549, shows data covering third rail clearances on various roads in the United States brought up to date as of November 1st, 1917.

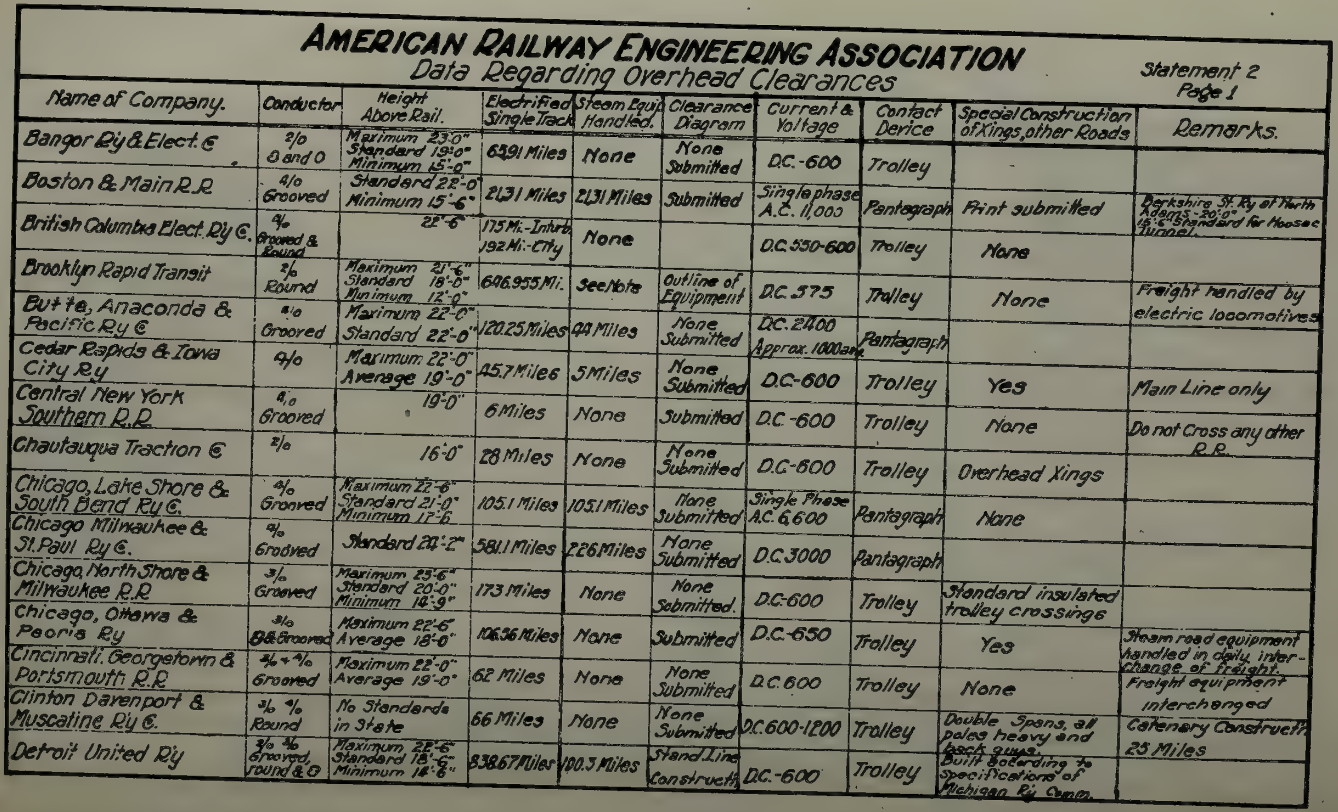
Tabular statement No. 2, sheets 1, 2, 3, 4, 5 and 6, on pages 550-555, shows data covering overhead clearances on electrified railroads brought up to date as of November 1st, 1917.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Data Regarding Third Rail Clearances.

Statement 1
Page 1

Name of Company.	Top or Under Contact.	Protected.	Uses Steam Equipment.	Structures Clear Prop. Lines.	Mileage in Operation.	Mileage Planned for Immediate Future.	Mileage Using Steam Equipment.	Remarks.
Albany Southern R.R. Co.	Top	No	No	Yes	53.50	None	None	1 mile O.H. trolley included in total.
Aurora, Elgin & Chicago.	"	"	Yes	No	98.68	None	98.68	
Baltimore & Ohio System.	"	Partly	"		9.40	None	9.4	Rail protected only at Stations
Boston Elevated Ry.	"	No	No		37.724	6.0	None	
Brooklyn Rapid Transit.	"	About 30%	"		218.492	Considerable	None	
Central California Traction Co.	Under	Yes	Emergency only	Yes	70.00	None	None	No steam operation for 4 Yrs.
Detroit River Tunnel Co.	"	"	Yes	"	25.70	None	25.70	2.7 miles O.H. Trolley included in total
Grand Rapids, Grand Haven & Muskegon.	Top	No	No		46.00	None	None	10 " " " " " "
Hudson and Manhattan R.R. Co.	"	Yes	"	No	20.00	None	None	Subway
Interborough Rapid Transit Co.	"	"	"	"	271.22	105.14	None	
Lackawanna & Wyoming Valley.	"	No	Yes	"	52.00	0.84	52.00	10 miles O.H. trolley
Long Island R.R. Co.	"	Yes	"		217.21	None	217.21	
Metropolitan West Side, Chicago.	"	No	No	No	163.10	None	10.0	16 miles O.H. sliding contact.
Michigan Ry. Co.	"	Partly	Yes		224.00	None	None	O.H. and underground conductors at Xings only.
New York Central R.R.	Under	Yes	"	Yes	264.13		264.13	22 miles O.H. conductors.
New York State Rys.	"	"	"		106.10	None	98.62	11.79 miles O.H. trolley.
Northern Electric Ry.	Top	Sta. grounds only	Emergency only	No	205.87	None	None	48 miles O.H. trolley included in total.
Northwestern Pacific R.R. Co.	"	stations only	Yes		35.5		35.5	
Pennsylvania R.R.			"		92.39		92.39	Philadelphia and vicinity.
Pennsylvania R.R. New York Div.	Top	Yes	"	Yes	102.74	None	22.70	1.18 miles O.H. contact excluded in total.
Penn'a. R.R. West Jersey & Seashore	"	"	"		150.26		150.26	8.37 miles O.H. trolley included in total.
Philadelphia & Western Ry. Co.	"	"	No	No	37.15	None	None	9 mi. O.H.T. Yards + Sidings not in Total.
Philadelphia Rapid Transit Co.	Under	"	No	"	19.30	None	None	Subway and elevated Lines.
Puget Sound Electric Ry.	Top	No	"	"	65.61	None	None	25 miles O.H. trolley included in total.
Sciota Valley Traction Co.	"	"	"	Yes	75.00	None	None.	" 3.95 miles trolley Urban included in total.
Wilkes-Barre & Hazelton Ry. Co.	"	Yes	No	slight	30.74	None	None	150 mi. O.H. trolley not in total on Lehigh Trac. Co.



AMERICAN RAILWAY ENGINEERING ASSOCIATION

Data Regarding Overhead Clearances

Statement 2
Page 1

Name of Company.	Conductor	Height Above Rail.	Electrified Single Track	Steam Equip Handled.	Clearance Diagram	Current & Voltage	Contact Device	Special Construction of Xings, other Roads	Remarks.
Bangor Ry & Elect. Co	2/0 8 and 0	Maximum 23'-0" Standard 19'-0" Minimum 15'-0"	63.91 Miles	None	None Submitted	D.C.-600	Trolley	-	
Boston & Main R.R.	4/0 Grooved	Standard 22'-0" Minimum 15'-6"	21.31 Miles	21.31 Miles	Submitted	Single phase A.C. 11,000	Pantagraph	Print submitted	Berkshire St. Ry at North Adams-20'-0" 15'-6" Standard for Hoosac Tunnel.
British Columbia Elect. Ry Co.	4/0 Grooved & Round	22'-6"	175 Mi.-Interb. 192 Mi.-City	None		D.C. 550-600	Trolley	None	
Brooklyn Rapid Transit	2/0 Round	Maximum 21'-6" Standard 18'-0" Minimum 12'-0"	696.955 Mi.	See Note	Outline of Equipment	D.C. 575	Trolley	None	Freight handled by electric locomotives
Butte, Anaconda & Pacific Ry Co	4/0 Grooved	Maximum 22'-0" Standard 22'-0"	120.25 Miles	44 Miles	None Submitted	D.C. 2400 Approx. 1000 am.	Pantagraph		
Cedar Rapids & Iowa City Ry	4/0	Maximum 22'-0" Average 19'-0"	45.7 Miles	5 Miles	None Submitted	D.C.-600	Trolley	Yes	Main Line only
Central New York Southern R.R.	4/0 Grooved	19'-0"	6 Miles	None	Submitted	D.C.-600	Trolley	None	Do not Cross any other R.R.
Chautauqua Traction Co	2/0	16'-0"	28 Miles	None	None Submitted	D.C.-600	Trolley	Overhead Xings	
Chicago, Lake Shore & South Bend Ry Co.	4/0 Grooved	Maximum 22'-6" Standard 21'-0" Minimum 17'-6"	105.1 Miles	105.1 Miles	None Submitted	Single Phase A.C. 6,600	Pantagraph	None	
Chicago Milwaukee & St. Paul Ry Co.	4/0 Grooved	Standard 24'-2"	581.1 Miles	226 Miles	None Submitted	D.C. 3000	Pantagraph		
Chicago, North Shore & Milwaukee R.R.	3/0 Grooved	Maximum 23'-6" Standard 20'-0" Minimum 14'-9"	173 Miles	None	None Submitted.	D.C.-600	Trolley	Standard insulated trolley crossings	
Chicago, Ottawa & Peoria Ry	3/0 8 & Grooved	Maximum 22'-6" Average 18'-0"	106.36 Miles	None	Submitted	D.C.-650	Trolley	Yes	Steam road equipment handled in daily interchange of freight.
Cincinnati, Georgetown & Portsmouth R.R.	4/0 + 4/0 Grooved	Maximum 22'-0" Average 19'-0"	62 Miles	None	None Submitted	D.C. 600	Trolley	None	Freight equipment interchanged
Clinton Davenport & Muscatine Ry Co.	3/0 4/0 Round	No Standards in State	66 Miles	None	None Submitted	D.C. 600-1200	Trolley	Double Spans, all poles heavy and back guys.	Catenary Construction 25 Miles
Detroit United Ry	2/0 3/0 Grooved, round & 0	Maximum 22'-6" Standard 18'-6" Minimum 14'-6"	838.67 Miles	100.3 Miles	Stand. Line Construction	D.C.-600	Trolley	Built according to specifications of Michigan Ry. Comm.	

AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Data Regarding Overhead Clearances.

Statement 2
Page 2

Name of Company	Conductor	Height Above Rail	Electrified Single Track	Steam Equip. Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction at Xings, other Roads	Remarks.
Erie Railway Co.	3/0 Grooved	Maximum 20'-0" Standard 22'-0" Minimum 16'-0"	38 Miles	34 Miles	None Submitted	11,000	Pantagraph	None	
Evansville Suburban & Newburgh Ry Co.	3/0 Grooved	Maximum 21'-6" Average 18'-0"	25 Miles	25 Miles	None Submitted	D.C 600		None	Operates Stand. Steam engines for Freight.
Fonda, Johnstown & Gloversville R.R.Co	4/0 Grooved	Max 22'-0" Steam Xings Standard 18'-0" Minimum 15'-0"	35½ Miles	½ Mile	None Submitted	D.C.600	Trolley	None	
Fort Dodge, Des Moines & Southern R.R.Co.	3/0 - 4/0 Grooved	Maximum 20'-0" Standard 23'-0" Minimum 21'-0"	150 Miles	None	None Submitted	D.C.-1200	Trolley 10 miles Pantagraph	None	
Galt, Preston & Hespeler Ry	3/0	Maximum 22'-6" Average 18'6"	22 Miles	½ Mile	None Submitted	D.C 600	Trolley	None	
Galveston Electric Co	2/0 Round	Maximum 22'-0" Standard 18'-0" Minimum 17'-0"	38.43 Miles	None	None Submitted	D.C. 600	Trolley		
Grand Trunk Ry System.	4/0 Grooved	Max. 22'0" in Yards 16'6" in Tunnel Min. 15'4" " "	12 Miles	12 Miles	Submitted	Single Phase A.C. - 3300	Pantagraph	None	
Great Northern Ry Co. (Cascade Tunnel)	2-4/0 Grooved 7' C. to C.	Max. 22'6" in Yards Min 17'6" in Tunnel 8' C. to C	7 Miles	7 Miles	Submitted	Three phase A.C. 6600 V. 25 Cyc.	Trolley	None	
Illinois Traction Systm	3/0 Grooved	Maximum 23'-0" Standard 19'-0" Minimum 18'-0"	510.8 Miles	510.8 Miles	None Submitted	D.C-600	Trolley	As per State Comm. rules, for height only	Handles Stand. Cars but no locomotives
Indianapolis & Louisville Traction Ry Co.	4/0 Grooved	Maximum 21'-0" Average 18'-0"	40.92 Miles	None	None Submitted	D.C. 1200	Trolley	Elevate trolley wires to clear legal requiremnts	Exchange equip. [Pass. + Freight] with Interstate Public Service Co.
Joplin & Pittsburg Ry Co.	4/0-0+B 2/0-0	Maximum 23'-0" Average 18'-0"	104 Miles	None	None Submitted	D.C.-600	Trolley	Wire 4' to 5' higher	Never operated with Steam.
Kansas City, Clay County & St. Joseph Ry Co.	4/0 Grooved	Maximum 23'-0" Average 19'-0"	70 Miles	None	None Submitted	D.C. 1400	Trolley		
Lake Erie & Northern.	4/0 Grooved	Maximum 22'-6" Standard 21'-6" Minimum 16'-6"	55.1 Miles	55.1 Miles	Submitted	D.C. 1500	Trolley & Pantagraph		
Lake Shore Elect. Ry Co.	4/0 Grooved	Maximum 22'-0" Standard 18'-0" Minimum 14'-0"	218 Miles	Practically all from outside connections	All new work	D.C. 650 (Trolley) 18000 (Trans.)	Trolley	None	
Lehigh Valley Transit Co.	2/0 - 4/0 Round & 8	Standard 18'-0"	216 Miles	None	None Submitted	D.C 600	Trolley		

AMERICAN RAILWAY ENGINEERING ASSOCIATION
Data Regarding Overhead Clearances.

Statement 2
Page 3

Name of Company	Conductor	Height Above Rail	Electrified Single Track	Steam Equip. Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction at Xings, other Roads	Remarks
London & Port Stanley Ry.	4/0 Catenary	23'-2"	24.6 Miles		None Submitted	D.C. 1500	Pantagraph	Yes	
Louisville & Northern Railway & Lighting Co.	3/0 Grooved	Maximum 22'-0" Average 20'-0"	20.74 Miles	None	None Submitted	D.C. 600	Trolley	Yes	Mileage includes Louisville Bridge and 189 Mi. of Louisville Ry.
Maryland Electric Rys.	4/0 Grooved	22'-0"	32 Miles	31 Miles	None Submitted	D.C. 1200	Pantagraph	None	Use Steam only for special movements and auxiliary freight service.
Mason City & Clear Lake R.R. Co.	2/0 Round	Maximum 23'-0" Minimum 21'-0"	20.6 Miles	None	None Submitted	D.C. 650	Trolley	None	Interchange Freight equip. with Steam Road
Minneapolis, Anoka & Cuyuna Range Ry Co.	4/0	Maximum 22'-0" Average 16'-0"	19.21 Miles	None	None Submitted	D.C 650	Trolley (shoe wheel)	Yes	
Montreal & Southern Counties Ry Co.	4/0 Grooved	Maximum 23'-0" Standard 22'-0" Minimum 19'-0"	57.5 Miles	25.2 Miles	None Submitted	D.C. 600	Trolley	None	
New York Central R.R. Co (Overhead)	0 & 2	So. 144th St. No. 144th St. Max 15'3" Max. 15'-5" Min. 15'-1" Min. 15'-3"	22 Miles	.0083 Miles		D.C 660	Shoe	None	Running Position 15'-4" Low. 14'7⅝" to 14'-9½" (N.Y.C) High. 15'5⅞" to 15'-6"
N.Y.N.H. & H R.R. Co (MAIN LINE)	4/0 0	Maximum 23'-0" Standard 22'-0" Minimum 15'-6"	500 Miles	500 Miles	Submitted	A.C 11,000	Pantagraph	Yes	
N.Y.N.H. & H.R.R. Co. (N.Y.W. & B.)	4/0 0	Maximum 28'-0" Standard 22'-0" Minimum 18'-0"	55 Miles	None	Submitted	A.C. 11,000	Pantagraph	Yes	
New York State Railways	4/0 Round	Maximum 22'-0" Standard 20'-0"	8.95 Miles	8.95 Miles	Submitted	D.C. 650	Trolley	None	22' Std on Elec. Steam roads and R.R. Crossings 20' Std on Trolley or City Lines
Niagra, St. Catharines & Toronto Ry Co.	4/0 Grooved	Standard 22'-6" Minimum 19'-0"	76 Miles	64 Miles	None Submitted	D.C. 600	Trolley	Catenary Constr.	
Norfolk Southern R.R. Co.	4/0 Grooved	Maximum 21'-0" Standard 21'-0" Minimum 19'-9"	65.81 Miles	3.637 Miles	Submitted	D.C. 550 A.C. 13,200 (25 Cycle)	Trolley		
Norfolk & Western Ry Co.	4/0 Grooved	Standard 24'-0" Minimum 23'-9"	106 Miles	106 Miles	Submitted	Trans 44,000 Line 11,000	Pantagraph	Foreign lines are required to cross using steel poles and giving 50' clear height above rail	
Northern Electric Ry	4/0 - 2/0	22'-0"	98 Miles	None	Submitted	D.C. 600	Trolley		
Northern Ohio Traction & Light Co.	4/0 Grooved	Max 22'-0" at R.R. Xings Standard 18'-0"	236 Miles	None	None Submitted	D.C. 600	Trolley		

AMERICAN RAILWAY ENGINEERING ASSOCIATION

Data Regarding Overhead Clearances.

Statement 2
Page 4

Name of Company.	Conductor	Height Above Rail	Electrified Single Track	Steam Equip. Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction at Xings, other Roads	Remarks.
Northern Texas Traction Co.	2/0-3/0-4/0	Maximum 23'-0" Average 19'-0"	113.86 Miles	None	None Submitted	D.C. 600	Trolley	None	
Oakland, Antioch & Eastern Ry.	4/0 Grooved	Maximum 22'-0" Standard 20'-0" Minimum 19'-0"	113 Miles	None	Submitted	D.C. 1200	Trolley	None	Height of Trolley now 22 ft. minimum in this State for all new construction
Ogden, Logan, & Idaho Ry Co.	2/0 & 4/0 Grooved	Interurban 22'-6" City 18'-0"	120 Miles	None	None Submitted	D.C. 750 to 1500	Trolley	Yes	
Ohio Electric Ry Co.	4/0 Grooved & Round	Maximum 22'-0" Standard 21'-0" Minimum 16'-0"	620 Miles	40 Miles	See Note	D.C. 600 to 650	Trolley	A.E.R.E. Assn.	Pole line 8'-0" from ℄ of track. Buildings 10'
Oneida Ry Co.	4/0 Round	Maximum 22'-0" Standard 22'-0" Minimum 22'-0"	8.95 Miles	8.95 Miles	Submitted	D.C. 650	Trolley	None	
Pacific Electric Ry Co.	3/0-4/0 Grooved	Maximum 22'-0" Standard 22'-0" Minimum 19'-0"	1061.64 Miles	18.66 Miles	Submitted	D.C. 600 & 1200	Trolley	Insulated Crossings	
Pacific Northwest Traction Co.	2/0 & 4/0 Round 00 Grooved 0000	Maximum 21'-0" Standard 20'-0" Minimum 19'-0"	61.94 Miles	61.94 Miles	Submitted	D.C. 600	Trolley	23' Clearance over steam lines	Includes Northern & Southern Divisions
Pennsylvania R.R. Co [New York Div.]	25 lb. rail "T" Shape	Maximum 15'-5" Standard 15'-4" Minimum 15'-2"	1.18 Miles	None	Submitted	D.C. 650	Pantagraph	None	
Pennsylvania R.R. Co [Philadelphia & Paoli Div.]	3/0 Grooved	Maximum 22'-0" Standard 22'-0" Minimum 15'-8½"	92.39 Miles	92.39 Miles	Submitted	Single phase A.C. 11,000	Pantagraph	None	
Pennsylvania R.R. Co [West Jersey & Seashore]	4/0 Grooved	Maximum 22'-0" Standard 22'-0" Minimum 18'-0"	8.37 Miles	8.37 Miles	Submitted	D.C. 675	Trolley	None	
Portland Railway, Light & Power Co.	1/0-3/0-4/0 Round & 8	City Interurban Max. 21'-0" 22'-0" Avg. 19'-0" 21'-0"	298.984 Miles	None	Submitted	D.C. 600	Trolley	Patented O.H. Frogs	184.973 miles City Lines Owned 13.456 " " " Operated n 114.011 " Interurban Lines.
Puget Sound Electric Railway.	4/0 Grooved	Maximum 22'-0" Average 19'-0"	25.49 Miles	None	Submitted	D.C. 600	Trolley	Trolley Height 22'	
Quebec Railway, Light, Heat & Power Co.	2/0 Round	Standard 21'-0"	96.89 Miles	46.89 Miles	None Submitted	D.C. 550	Trolley	Built according to Specifications of Canadian Ry. Commission	
Rhode Island Co.	3/0-4/0 Round & Grooved	Max. 22'-0" at R.R. Xings Standard 19' to 20' Min. 13'-0" under Br.	391.816 Miles		None Submitted	D.C. 600	Trolley		
Rock Island Southern Ry	3/0 8-Grooved	Maximum 22'-0"	15 Miles	None	None Submitted	D.C. 600	Trolley	None	

AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Data Regarding Overhead Clearances.

Statement 2
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Name of Company	Conductor	Height Above Rail.	Electrified Single Track	Steam Equip. Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction at Xings other Roads	Remarks.
Salt Lake & Utah R.R.Co.	4/0 Grooved	Maximum 23'-0" Standard 22'-0" Minimum 18'-0"	92 Miles	None	Submitted	D.C. 1500	Trolley	In accordance with General Order No. 10 Public Utilities Comm. of Idaho	
San Francisco, Napa & Calistoga R'y	3/0 Grooved	19'-0"	41.6 Miles	None	None Submitted	A.C. 3300	Pantagraph	None.	
Southern Illinois R'y & Power Co.	4/0 Grooved	Maximum 22'-0" Average 18'-0"	17 Miles	None	None Submitted	D.C. 1200	Trolley	None	
Southern New York Power & Ry Corporation	2/0	Average 18'-0"	68 Miles	None	None Submitted	D.C. 500	Trolley	Yes	
Southern Pacific Co. [Oakland, Alameda & Berkeley]	4/0 Grooved	Maximum 22'-0" Standard 22'-0" Minimum 17'-6"	118.28 Miles	34.4 Miles	None Submitted	D.C. 1200	Pantagraph	Double insulation with grounded Section	
Southern Pacific Co. [Portland Div.]	4/0 Grooved	Maximum 23'-0" Average 22'-0"	163 Miles	144 Miles	Submitted	D.C. 1600	Pantograph	Double insulation with Ungrounded Dead Section	
Spokane, Portland & Seattle Ry. [Oregon Elect. Ry]	4/0 Grooved	Maximum 23'-0" Standard 22'-0" Minimum 16'-0"	192.87 Miles	See Note	None Submitted	D.C. 10 miles 600 V. 187.87 - 1300 V.	Trolley	See print	During extensions steam used on all lines except 1.9 miles in city
Spokane, Portland & Seattle Ry [Spokane & Inland Empire]	3/0 - 4/0 8 + Grooved	Maximum - 22'-0" Average 19'-0"	184.4 Miles	None	None Submitted	A.C. 6600 → D.C. 600 →	Pantagraph Trolley	None	Inland Div. & Coeur d'Alene Div.
Spokane, Portland & Seattle Ry. [United Ry's Co.]	4/0 Grooved	Maximum 23'-0" Standard 22'-0" Minimum 17'-8"	32.55 Miles		None Submitted	D.C. 600 - 10.39 mi. D.C. 1200 - 22.16 mi.	Trolley	Limited insulation.	
Tacoma Ry & Power Co.	2/0 Round	Maximum 22'-0" Average 19'-0"	125.34 Miles	None	None Submitted	D.C. 600	Trolley	Trolley height 22'-0"	Includes Pacific Traction Co.
Tarrant County Traction Co.	4/0 Grooved	Maximum 23'-0" Standard 19'-0" Minimum 17'-0"	29.52 Miles	None	None Submitted	D.C. 600	Trolley	National Trolley Guard	
Texas Electric Ry	4/0 Grooved	Maximum 23'-0" Standard 19'-0" Minimum 17'-0"	218.617 Miles	None	None Submitted	D.C. 600 + 1200	Trolley	None	
Toledo & Western Ry	4/0 8	Maximum 21'-0" Standard 18'-0" Minimum 16'-0"	85.6 Miles	85.6 Miles	None Submitted	D.C. 600	Trolley	Basket the line also towers over foreign lines	
Twin City Lines Minneapolis Minn.	3/0 8	Maximum 22'-6" Standard 18'-0" Minimum 12'-4"	449.69 Miles	None	None Submitted	D.C. 600	Trolley	22'-0" trolley above Steam road tracks	
Union Traction Co. Indiana.	1/0 - 3/0 - 3/0 Round, 8 + Grooved	Maximum 22'-0" Stand 18'-0" to 20'-0" Min. 15'-0" to Bridges	408 Mi. Inter 45 Mi. City	1 Mile	Submitted	D.C. 600 to 650	Trolley	None	

AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Data Regarding Overhead Clearances.

Statement 2
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Name of Company	Conductor	Height Above Rail.	Electrified Single Track	Steam Equip. Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction at Xings, Other Roads	Remarks
Visalia Elect. R.R	3/0	22'-0"	48.68 Miles	16.64 Miles	None Submitted	A.C. 3300	Pantagraph	None	
Walla Walla Valley Ry Co	4/0	21'-0"	27.74 Miles	None	None Submitted	D.C. 575	Trolley		
Washington Baltimore & Annapolis Elect. R.R. Co	4/0 Grooved	Maximum 21'-0" Standard 19'-0" Minimum 15'-0"	98 Miles	20 Miles	None Submitted	D.C. 1200	Trolley	None	
Washington & Old Dominion Ry.	4/0 Grooved	22'-0"	88.5 Miles	53.5 Miles	None Submitted	D.C. 650 A.C. 33000	Trolley	None	
Waterloo, Cedar Falls & Northern Ry Co.	4/0 Grooved 2/0 Round.	City Interurban Max. 22'-0" 23'-0" Stand. 18'-6" 21'-0" Min. 16'-0" 18'-6"	136.58 Miles	118.09 Miles	None Submitted	D.C 650 & 1300	Trolley	A.E.R.E.A. Standard specifications	
Western New York & Penna. Traction Co	4/0	Maximum 22'-0" Minimum 18'-0"	99 Miles	None	None Submitted	D.C. 600	Trolley	Trolley Guard	Interchange Freight equip with 4 Steam Rds.
Western Ohio Ry Co	2/0 Round	18'-0"	112 Miles	None	None Submitted	D.C 650	Trolley	None	
Youngstown & Southern Ry. Co	3/0 Grooved	Standard 18'-0"	20 Miles	None	None Submitted	D.C. 625	Trolley	None	

(ITEM 5) TRANSMISSION LINES AND CROSSINGS.

SUB-COMMITTEE NO. 3.

R. D. Coombs, *Chairman;*	Frank Rhea,
H. M. Bassett,	J. R. Savage,
D. J. Brumley,	A. G. Shaver,
J. A. Peabody,	H. U. Wallace.

There has been assigned to this Sub-Committee that portion of the National Electrical Safety Code prepared by the U. S. Bureau of Standards, issued as Circular No. 54 (Second Edition, November 15th, 1916) which prescribes the requirements for the crossings of overhead and underground wires and cables over railroad company's rights of way. The Committee has prepared a comparison of the requirements of the A. R. E. A. crossing specifications and the provisions of the code, and this comparison will be found under the Committee's report on the National Electrical Safety Code.

There has been no meeting of the National Joint Committee on Overhead and Underground Line Construction, to which your Committee formerly sent delegates, since July 16th, 1915, and the work of this Committee has virtually been absorbed by the U. S. Bureau of Standards and is reflected in the wire crossing requirements of the National Electrical Safety Code.

There was also assigned to this Committee, Item 5, on the proper type of overhead catenary construction, with particular reference to the consideration of providing clear vision for signal and co-operating with the Committee on Signals and Interlocking. Mr. J. A. Peabody, Chairman of the Committee on Signals and Interlocking, and Mr. A. G. Shaver of that Committee, both members of this Committee, served as co-operating representatives. The following illustrations are presented as typical of catenary construction in actual service and offering the least obstruction to the view of signals:

Single track, using wood pole supports:

Fig. 1 and Fig. 2—A light signal.
Fig. 3 and Fig. 4—Semaphore signals.

Two or more tracks, using steel supports:

Fig. 5—Supported semaphore on curve.
Fig. 6—Position light signal.
Fig. 7—Suspended semaphore on curve.

Yard tracks, using steel supports:

Fig. 8—Supported semaphores on a catenary bridge.

Under bridge or subway tracks:

Fig. 9—Light signal.

It must be emphasized that it is difficult by photographs or other illustrations, to clearly or accurately show the real effect of the background or other structures on the view of signals. However, it is hoped that the accompanying illustrations will indicate the approximate average condition for the different classes of construction.

In situations such as shown in Figs. 7 and 9, i. e., on sharp curves or where overhead streets are frequent, it is difficult to arrange an entirely satisfactory view of signals.

In Fig. 10 is shown diagrammatically the span wire—guyed pipe post type of catenary construction, while Fig. 11 is typical of an anchor bridge to be used in conjunction with the construction shown in Fig. 10.

Good practice requires that anchor bridges should be located at points suitable for the location of signals, in order that they may be used for combined service.

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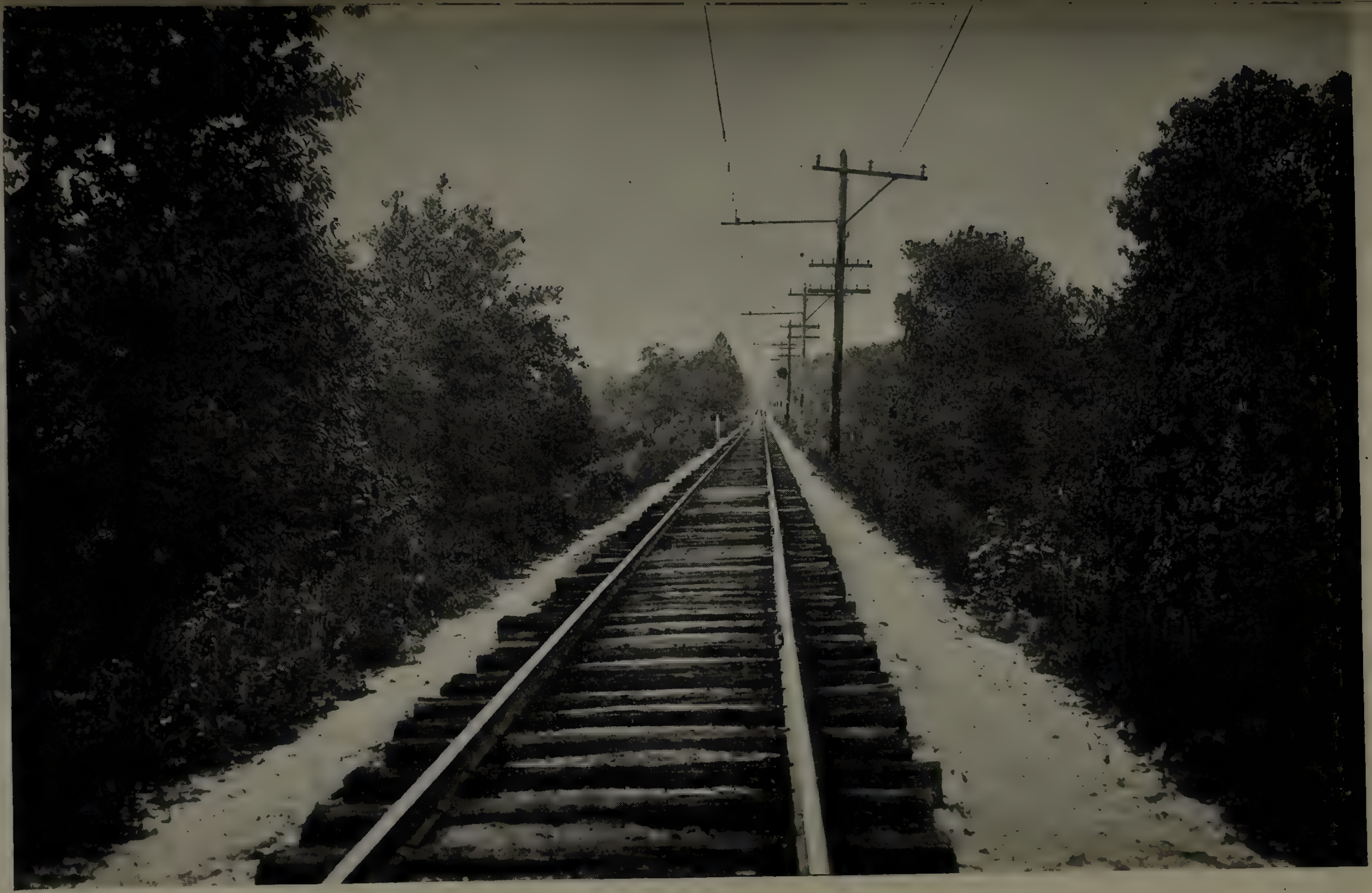

FIG. 2.

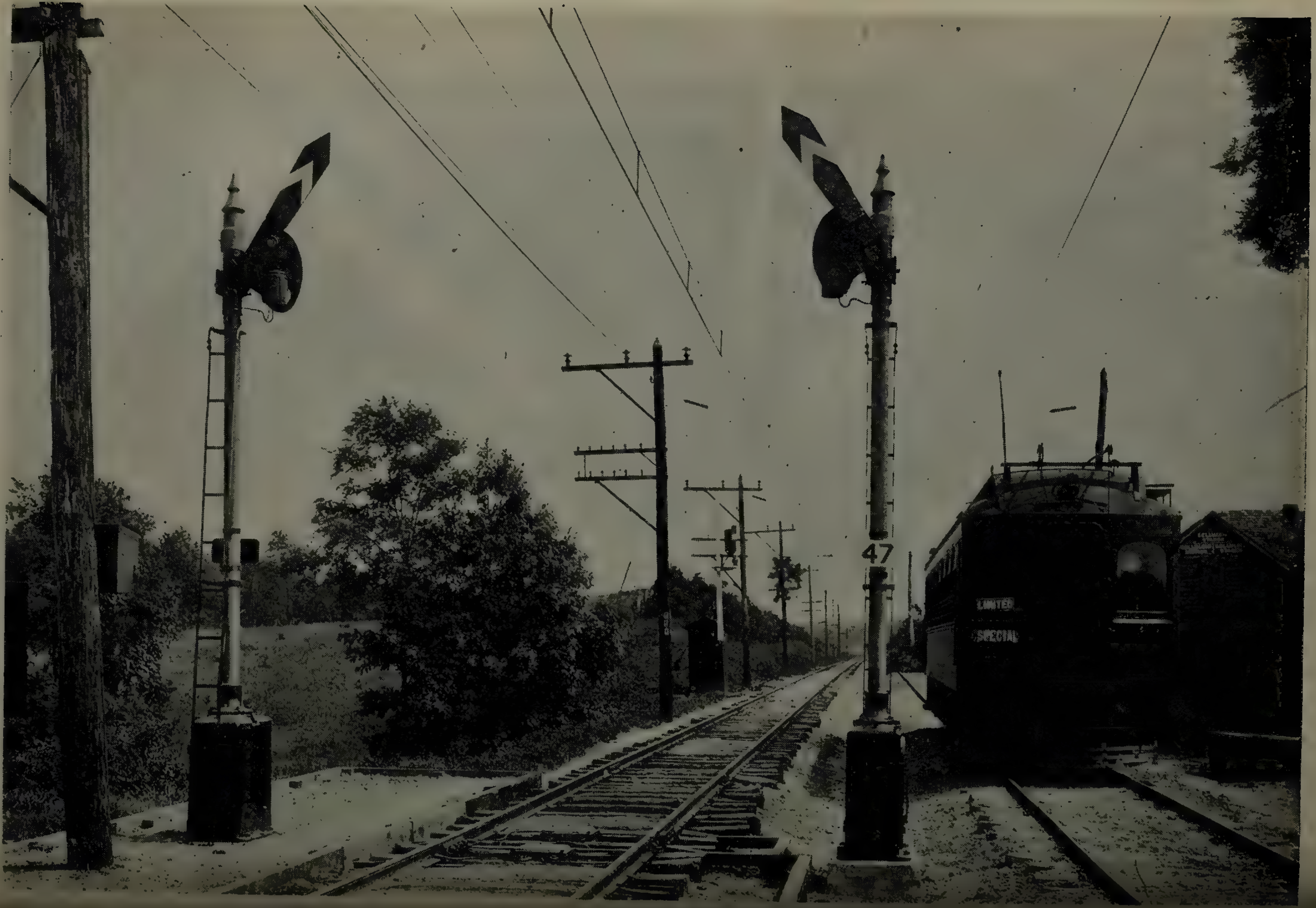

Fig. 3

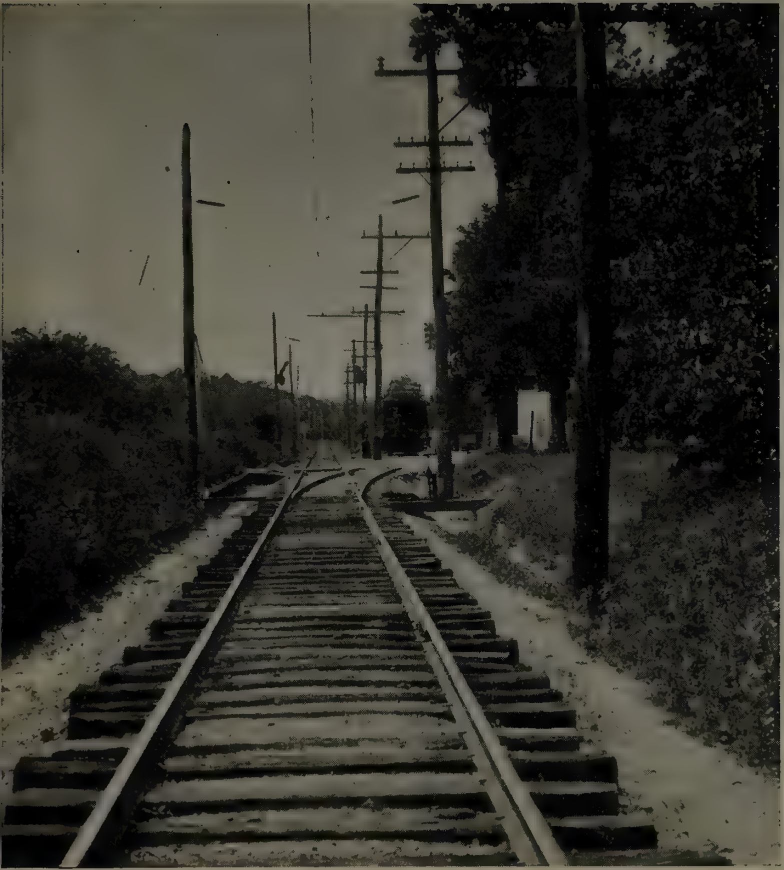

FIG. 4.

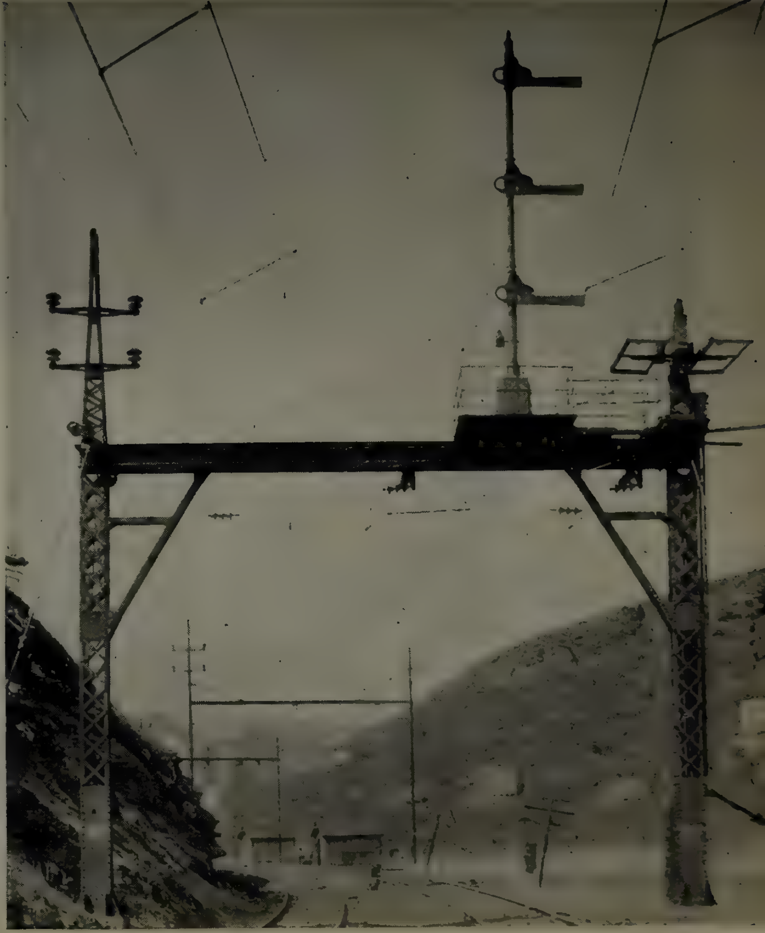

FIG. 5.

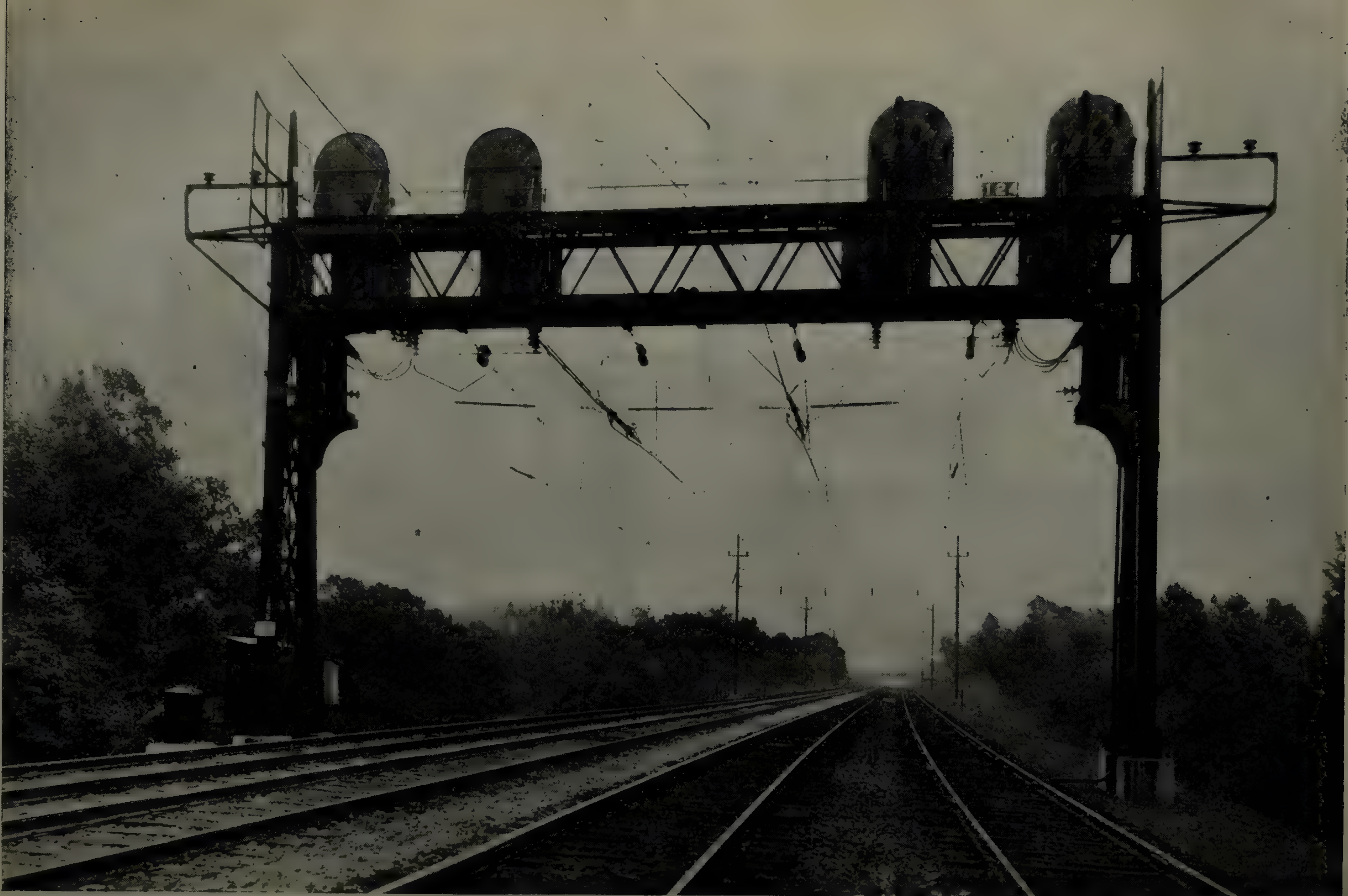

FIG. 6.

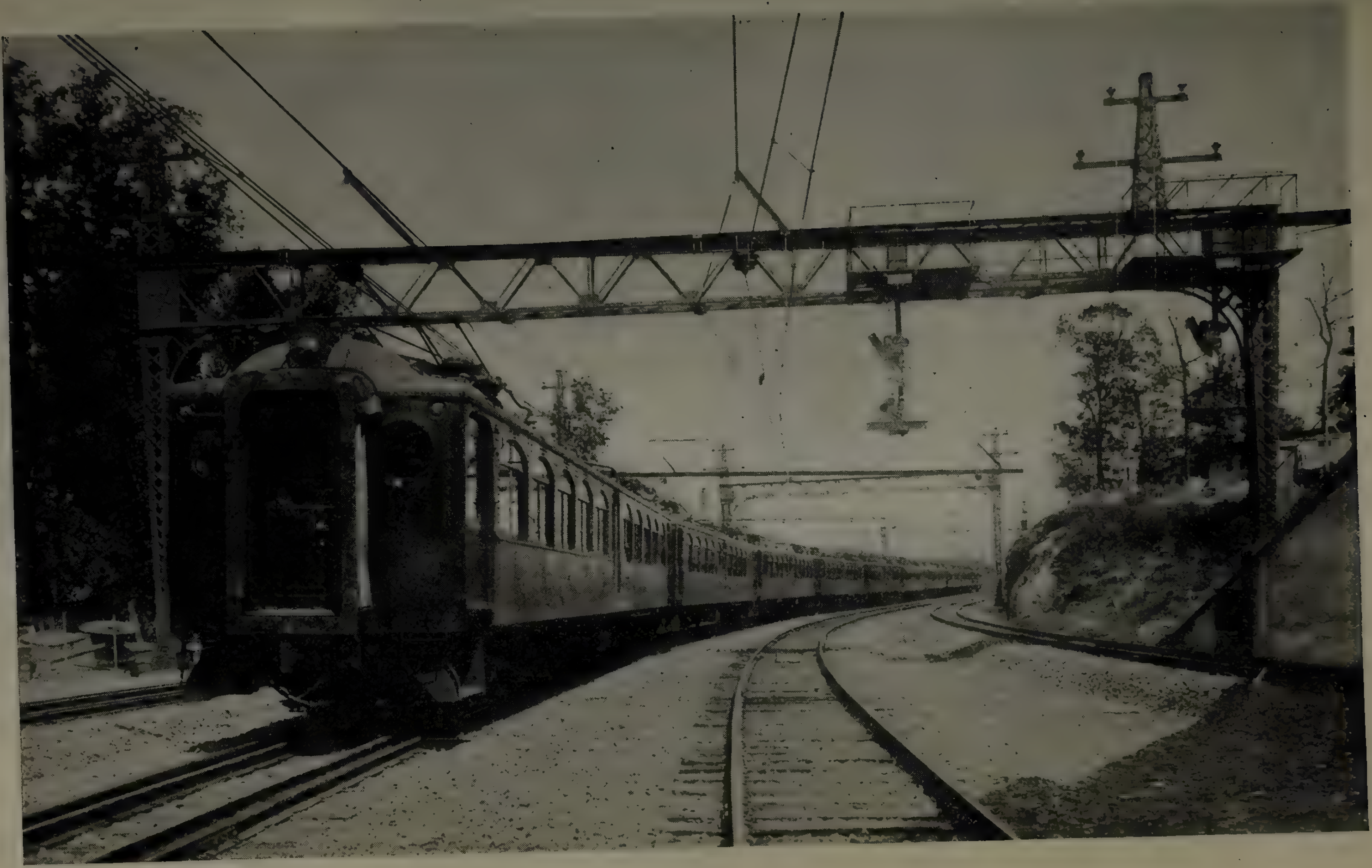

FIG. 7.

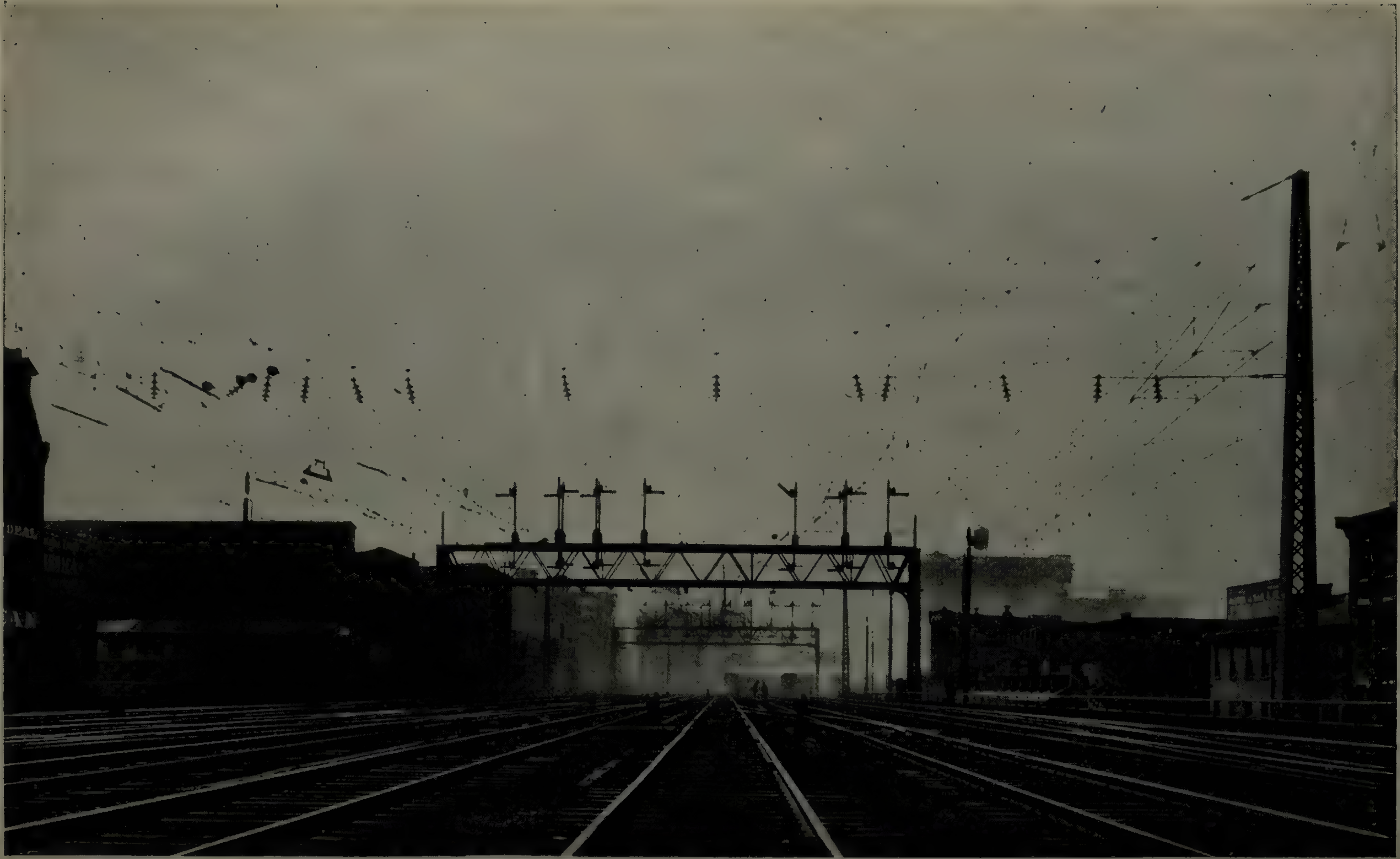

FIG. 8.

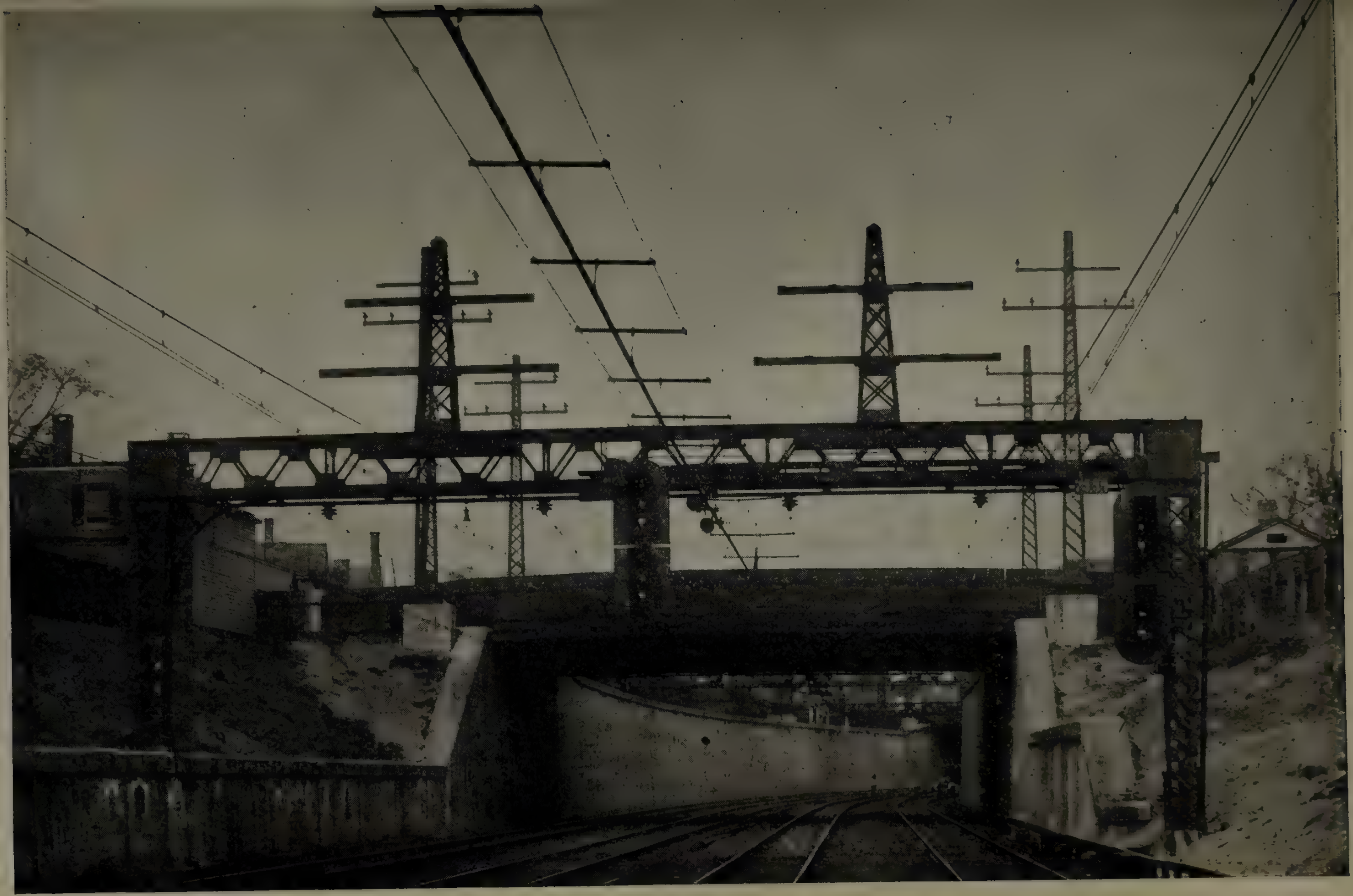

FIG. 9.

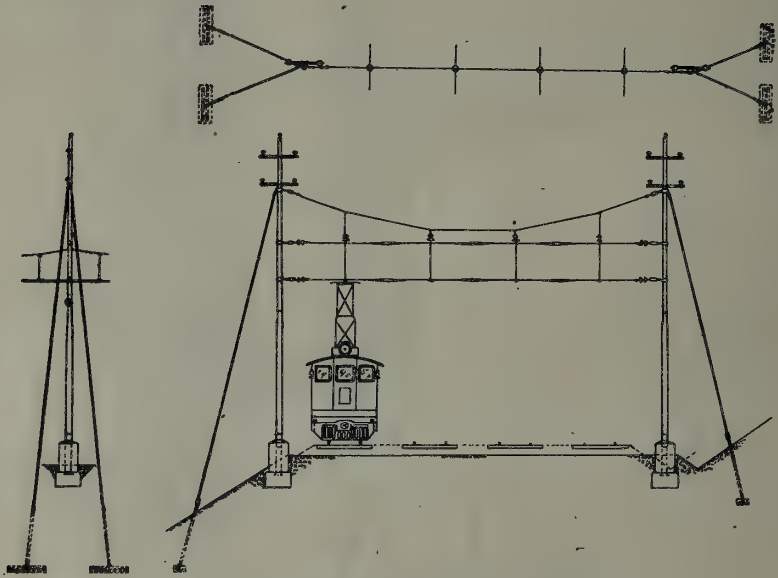

FIG. 10.—FOUR-TRACK MAIN LINE CROSS CATENARY SPAN.

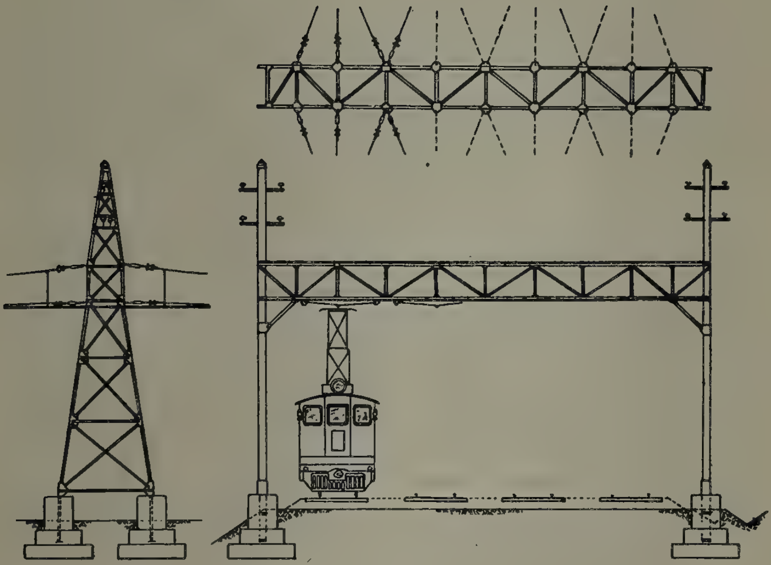

FIG. 11.—FOUR-TRACK MAIN LINE ANCHOR BRIDGE.

(ITEM 3) ELECTROLYSIS AND INSULATION.

SUB-COMMITTEE NO. 4.

E. B. KATTE, *Chairman;*	R. H. FORD,
J. D. BRUMLEY,	W. S. MURRAY,
R. D. COOMBS,	M. SCHREIBER,
A. O. CUNNINGHAM,	H. U. WALLACE.

There will be no report this year on the subject of Electrolysis for the reason that your Committee has confined its activities to representation on the American Committee on Electrolysis. The latter committee has adjourned all meetings and discontinued its sub-committee work for the duration of the war in accordance with the recommendation of its Chairman, Mr. B. J. Arnold, contained in his circular letter of October 5th, 1917.

The Committee has no report to offer on the subject of "Insulation," and requests further instruction from the Board of Direction regarding their desires in connection with a report on this subject.

ELECTROLYTIC EFFECT ON CONCRETE IN SALT WATER.

Perhaps the most popular theory of the failure of concrete structures, particularly reinforced concrete in salt water, is that it is caused by electrolysis action. As a matter of fact, the failure of any such structure may be due to a combination of causes. There is little real or reliable information on this subject up to this time. A member of the Committee, Mr. Schreiber, had the occasion to investigate the effect of salt water on concrete in connection with a report on a proposed vehicular tunnel across the Hudson River at New York, the early part of this year, and the information on record at that time in this respect was very meager. Since then, a number of articles have appeared in the technical press, notably the Engineering News-Record, that have clarified the proposition considerably.*

Concrete properly mixed and placed without construction seams and with a dense surface will undoubtedly successfully resist sea water action. In extreme cases it may be necessary to protect the exposed surface of the concrete with facing material in order to prevent any physical abrasion. On the other hand, when physical abrasion appears, the concrete disintegrates, due to the chemical action of the salt on the lime in the cement. It has been shown through laboratory experiments by the U. S. Bureau of Standards that salt solutions will percolate through hollow cylinders resulting in the destruction of the cement mortar when a sufficient amount of salt accumulates and crystallizes out. In actual practice, when green concrete is installed, the lime in the cement at or near the surface is in a form which will readily combine with the carbon dioxide in the atmosphere. So there is formed at the surface and for a slight depth into the mass, lime carbonate (limestone), which is practically insoluble in sea water. This layer or skin of insoluble material acts as an armor to the uncarbonate cement in the interior of the concrete mass. If the concrete is deposited in water it does not get carbon dioxide from the air, but a sufficient amount of carbon dioxide is obtained from the water to get this protective coating. It appears that if this is true, then the lime in the cement in the interior of the concrete would carbonate when exposed to accidental abrasion. But, the reason this does not take place is the fact that as the cement hydrates over a period of months in the interior of a mass of concrete where not exposed to carbon dioxide, the lime, which is freed as the cement ages, is changing from the amorphous to the large crystalline form which is soluble in sea water.

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*Engineering News-Record, Sept. 20, Oct. 4, Oct. 11, Oct. 18, Oct. 25th, 1917. Engineering News, Vol. 53, p. 345, and Vol. 60, p. 453. Engineering Record, Vol. 63, p. 655. Also see the proceedings of the Franklin Institute, November, 1917, paper by Prof. J. M. Craighton.

When a concrete surface is abrased by the action of waves, ice, or floating debris, the destruction of coating allows the salt water to soften the cement by its action on the lime, and disintegration starts. The water washes away the softened section and a new area is exposed ready for further disintegration.

Now in the case of reinforced concrete, we have an additional effect to consider—the action of salt water on iron or steel reinforcing material. Iron ordinarily contains carbon, sulphur and other ingredients. Their presence cause a difference in potential so that there exists here and there throughout the mass a sort of auto or galvanic electrolysis. Moreover, even when fresh water seeps through the concrete, an electric current may be set up, the water acting as an electrolyte that finally results in the disintegration of the iron or steel, which is replaced by iron oxide (ordinarily called rust). As the iron oxide occupies a larger volume than a corresponding amount of iron, there will be developed an enormous expansive force which is sufficient to crack the strongest concrete and force it away from the reinforcing rods.

However, when you place the reinforcing concrete in salt water you have a much better electrolyte than plain water, so that the rusting effect on iron is accelerated. Once this process begins, it is easily understood how the disintegration will be hastened with the opening of cracks, allowing more salt water to seep through the concrete along the rods, not mentioning the effect of freezing and the chemical action of salt water on the lime of the cement in the concrete proper.

It is not strange that the deterioration of both the plain and reinforced concrete always occurs above the water line when you consider that below the water line the limestone or armor coating of the concrete is seldom or ever disturbed, either by mechanical or aerial agents. Above the water line salt accumulates by capillarity and evaporation and the absorption of the concrete of air carrying very minute particles of sea water. The chlorine and oxygen coming from the sea air and salt water form a very active corroding agent, and the salt air is now known to penetrate unprotected concrete to a considerable depth.

So it seems that, although the disintegration of concrete may be laid at the door of electrolytic action to some extent, it is possible to design and install the work so as to reduce the disintegration to a minimum. The concrete should be made dense, the mixture richer and the quality of the work better than would otherwise be necessary. A good method of determining the proper mixture to give the greatest density is to take trial batches of concrete. The concrete should be just dry enough to permit of light tamping. There should not be too little or too much water. Sharp corners, feather edges and construction seams should be avoided so that there will not be an opportunity for the starting of abrasion or the interference with the protective coating. Likewise, the reinforcing steel or iron should be free from impurities as far as it is practicable and should not be placed too near the surface. It is not well to put any dependence on plastering a structure after it is completed. A face of precast blocks, cut stone or any masonry material that is tough and dense will protect the concrete against any abrasion and will go a long way toward making an invulnerable structure.

(ITEM 4) MAINTENANCE ORGANIZATION AND RELATION TO TRACK STRUCTURES.

SUB-COMMITTEE NO. 5.

C. E. Lindsay, *Chairman;*
Z. M. Briggs,
Walt Dennis,
W. L. Morse,
J. R. Savage.

Owing to the fact that this Committee reported quite fully last year and the desire of the Board of Direction that the number of subjects to be reported on by each committee be restricted, there will be no report this year on Maintenance Organization and Its Relation to Track Structures. The Committee, however, is keeping in touch with the general development of the art and the assembling of data for the preparation of a future report.

(ITEM 6) WATER POWER.

SUB-COMMITTEE NO. 6.

W. S. Murray, *Chairman;*
Z. M. Briggs,
D. J. Brumley,
R. H. Ford,
M. Schreiber,
Frank Rhea,
H. U. Wallace.

Your Committee is of the opinion that all water power developments, both from the point of view of generation and utilization, are subject to such wide variations, both physical and operative, that every situation is individual to itself; and it is your Committee's conviction that now, as never before, there is reason for railroads to investigate anew the financial possibilities to be gained by the development of some of the water powers within their territories, which, under past conditions, may have been considered unprofitable.

The Committee reports progress and suggests the following underlying principles as governing a choice between steam and water power developments, or the use of combined water and steam plants.

1.—The increased cost of coal, being the largest single factor of cost, outside of fixed charges, in the production of steam generated power, places such higher values upon hitherto undeveloped water powers.

2.—Water power on rivers, the average stream flow which can be increased by storage, may now figure attractively against steam generated power in some locations.

3.—Water powers on rivers from which continuous flow cannot be obtained may now figure attractively in combination with steam plants against steam development alone.

In connection with Water Power Developments, and their relation to steam auxiliary plants, reference is made to the two following papers:

"The Economic Capacity of Combined Hydro-Electric and Steam Power Plants," by Cary T. Hutchinson, Part I, Vol. 33, page 138, American Institute of Electrical Engineers, and "Economical Combination of Water Power and Steam Plants and a Convenient Method of Solution," by H. St. Clair Putnam, presented at the Thirty-fourth Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va. (Will later be published in the A. I. E. E. Transactions.)

The Committee recommends that the subject be continued and studied during the coming year in collaboration with Committee XIX, having in charge the matter of Conservation of Natural Resources.

(ITEMS 7 AND 8) ELECTRICAL INTERFERENCE.

SUB-COMMITTEE NO. 7.

R. H. Ford, *Chairman;*	J. R. Savage,
W. S. Murray,	M. Schreiber,
J. A. Peabody,	A. G. Shaver.

Two subjects were referred to this Committee by the Board of Direction as follows:

(Item 7) Report recommended practice for eliminating, as far as practicable, interference with telephone and telegraph lines caused by the use of propulsion circuits.

(Item 8) Report on the interference with telegraph and telephone circuits by the use of direct current propulsion circuits and methods of eliminating the effect as far as practicable.

Your Committee has given the subject consideration and since the subject is an important one and is now a matter of investigation by specialists employed by the telephone and telegraph interests, as well as by the manufacturers of electrical appliances, your Committee has decided to make no report this year, but to recommend that the subject be continued for further consideration during the coming year.

CONTRACT FORM ON LOCATION OF POWER LINES AND WIRES ON RAILROAD COMPANIES' RIGHTS OF WAY.

SPECIAL SUB-COMMITTEE.

R. H. Ford, *Chairman;* J. A. Peabody.
C. E. **Lindsay,**

There has been referred to this Committee by the Secretary, Mr. E. H. Fritch, a form of contract prepared by the General Managers' Association of the Southeast, relative to terms upon which power lines may be permitted to locate poles on railway rights of way.

The General Managers' Association of the Southeast is an organization composed of fifty-six railroads operating in the territory east of the Mississippi and south of the Ohio rivers. It appears that this form was adopted by that association as recommended practice on November 12th, 1914, as to the terms of occupancy, and on April 26th, 1917, as to form of contract.

It is recognized by the Committee that there are presented many problems in the preparation of a general form of this character which will be sufficiently elastic to comply with the manifold conditions existing on railroads which may be widely separated and with whom conditions may be vastly different, and unless, in their preparation forms of this and like character are considered from every angle and prepared with great care, they may at times cause embarrassment and result in complications with public or private bodies, due to the fact that their approval by one railway may be used as a reason that they should likewise be approved by another railroad where conditions may be quite different.

It is believed by your Committee that it would be unwise to suggest changes therein, which appear desirable to this Committee, because it is recognized that there does not now exist any proper source to which such matters may be referred for final revision.

Your Committee recommends that this subject be referred to a committee composed of members from the proper standing committees of the American Railway Association and of the American Railway Engineering Association.

(ITEM 10) PROPOSED NATIONAL ELECTRICAL SAFETY CODE.

The preliminary edition of the proposed National Electrical Safety Code was issued April 29th, 1915, and submitted for criticism by Dr. E. B. Rosa, Chief Physicist, U. S. Bureau of Standards, Department of Commerce, Washington, D. C. Since that time the Code has been the subject of discussion by the officers of the Bureau of Standards and by the Code is to prescribe good electrical practice for all industries, including representatives of the national engineering societies. The object of the railroads, and will be recommended by the Bureau of Standards to the various Public Service Commissions and other State legislative bodies for adoption as mandatory law.

The second edition of the Code was issued November 15th, 1916, for examination, trial and constructive criticism. On July 16th, 1917, your Secretary wrote to the members of the Association, advising them of the desire of the Bureau of Standards for the co-operation of steam railroads in the perfection of this Code, and inviting comments or criticisms. In the same circular you were advised that the Committee on Electricity had been charged with the duty of collecting such comments and criticisms from steam railroad officials and transmitting them to the Bureau of Standards with its recommendations. You were requested to have your criticisms in the hands of the Committee not later than December 1st, 1917.

Your Committee has had the benefit of the comments and suggestions of 21 railroad officials and, in most instances, these comments reflect the advice of a staff of technical assistants. Generally, the comments are favorable and the need of a unified code for all states is recognized. However, the present code has been criticized as being cumbersome and difficult to follow because of the many cross references. The most serious defect in the code relates to the requirements for the crossing of foreign wires and cables over railroad company's right of way. The standards used for many years by the railroad companies have been reduced in some important details, as will be shown in the comparison of the A. R. E. A. specifications for overhead transmission line crossings.

The Code is divided into an Introduction and Four Parts. The Introduction describes the purposes of the Code, gives a brief history thereof and defines the meaning of the electrical terms used.

Part I defines the rules for the installation of machinery, switchboards, wiring, etc., in central power stations and sub-stations. Your Committee is of the opinion that none of the requirements of this part of the Code will prove objectionable.

Part II defines the rules for the construction of overhead and underground lines for the transmission and distribution of electrical energy and intelligence. Comments in detail will follow.

Part III defines the rules for the installation of electrical apparatus in factories and residences and wherever electricity is utilized for heat, light and power. Your Committee is of the opinion that none of the requirements of this part of the Code will prove objectionable.

Part IV defines the rules for safeguarding employes when working on or near electrical machines and lines. No adverse criticisms of this portion of the Code have been received by your Committee, except with regard to its legality as more fully noted below.

The features of the Code which your Committee desire especially to bring to your attention are briefly described under the following headings:

- (A) Legal Aspect.
- (B) Electrical Features.
- (C) Structural Features.
- (D) Transmission Crossing Requirements.
- (E) General Conclusions.

(A) Legal Aspect of the Code.

The proposed Safety Code is open to debate in three essential legal aspects, namely:

Inspection.—There has been found no record of any instance where inspection has been made compulsory by the affirmative force of law. Where government has thought it imperative to require inspection, it has usually taken upon itself that duty. In this way, fire escapes, boilers, explosives, etc., are inspected.

Authority of a Public Service Commission.—The legal opinion is expressed that it is doubtful whether the statutes will permit the adoption of general rules, such as proposed, by the Public Service Commission. The making of laws is a legislative function and the statutes do not especially grant commissions the power to adopt such laws. There seems to be, however, no doubt but that a uniform code would be more desirable than separate and conflicting regulations in the various states.

Validity of Part IV.—The opinion has been expressed that in its present form, it is extremely doubtful whether Part IV can be made valid law as a statute or as an administrative order. It is probable that the provisions of the Code are generally reasonable and there can be no objection because of its tendency to promote the safety of employes, but valid objections to Part IV may be based upon the inflexible nature of the language and its interference with the private management of business to an extent not justified in the interests of safety.

(B) Electrical Features of the Code.

In detail the criticisms of the electrical portion of Part II are as follows:

Rule 151, Mechanical and Thermal Protection.—There has not been found in the Code any clause covering the installation of wires and cables where they are subjected to excessive surrounding temperatures. The following is suggested to follow Clause 151d:

> "Wherever insulated conductors are exposed to excessive surrounding temperatures, a special protection shall be provided if the maximum temperature exceeds the maximum safe limiting temperatures adopted in the Standardization Rules of the A. I. E. E. (Article 677)."

Rule 221, Conductor—Materials and Minimum Sizes.—A minimum size No. 8 wire is permitted by the Code. Nothing smaller than No. 6 should be used.

Rule 223, Recommended Normal Sags.—The Code recommends for a given size of wires and for Grades A, B and C, sags varying from 22 in. to 27 in. at 60 deg. Fahr., for 150-ft. spans. For the same size and spans the A. R. E. A. specifications requirement is 36 in. at 60 deg. Fahr., which is more conservative and should be adhered to.

Rule 231, Cross Arms and Conductor Fastenings.—The Code permits the use of wooden pins for over 5000 volts. This is not permitted by the A. R. E. A. specifications. Double cross arms at crossings poles are not required by the Code, but are called for in the A. R. E. A. specifications.

Rule 240, Clearances Over Railroad Tracks.—This is one of the most important points wherein the Code proposes to reduce the A. R. E. A. requirements. The Code clearances are based on 60 deg. Fahr., no wind and for spans not greater than 150 ft. The A. R. E. A. specifications are for clearances under the most unfavorable conditions. The comparison is as follows:

CLEARANCE BETWEEN TOP OF RAIL AND CROSSING WIRE.

Variation in Voltage.	*Code.*	*A. R. E. A.*
For wires of less than 300 volts to ground	27 ft.	30 ft.
For wires of 300 volts to 15,000 volts	28 ft.	30 ft.
For wires of 15,000 volts to 50,000 volts	30 ft.	30 ft.
Above 50,000 volts add ½-in. per 1000 volts, inc.		30 ft.

The Code permits a reduction of the above clearances to 25 ft. for wires carrying voltages up to 15,000 when paralleling contact conductors. The A. R. E. A. specifications permit this reduction in clearance for constant potential, direct current circuits not over 750 volts. The requirements of the A. R. E. A. specifications should not be reduced.

Rule 241, Minimum Values for Conductor Clearances and Separations.—In the Code the conductor separations are for conductors whose sags do not exceed 3 ft. The separation specified in the A. R. E. A. specifications are for the conductors carrying a. c. current and spans not exceeding 150 ft. Following is a comparison:

SEPARATION BETWEEN CONDUCTORS.

Variation in Voltage.	*Code.*	*A. R. E. A.*
0-7500 Volts.	12 In.	12 In. up to 7000 v.
7500-14000	12 to 14.6	20
14000-27000	14.6 to 19.8	30
27000-35000	19.8 to 23.0	36
35000-47000	23.0 to 27.8	45
47000-70000	27.8 to 37.0	60
70000-and up	.4-in. per 1000 v.	

The clearance from the supporting structures (except insulators) are compared below:

Clearances Between Conductors and Structures.

Variation in Voltage.	*Code.*	*A. R. E. A.*
0-7500 Volts.	3 In.	9 In. up to 10000 v.
Above 7500 volts the code requires an addition of .25-in. per 1000 excess.		
10000-14000	3.625 to 4.624	12
14000-27000	4.624 to 7.875	15
27000-35000	7.875 to 9.875	18
35000-47000	9.875 to 12.875	21
47000-70000	12.875 to 18.625	24
70000-and up	.25-in. per 1000 v.	

Rule 267, Protection Against Conductor Breakage.—The Code permits splices in spans adjacent to the crossing span, whereas such splices are prohibited by the A. R. E. A. specifications. The grounding of poles is not required in the Code and is a protection afforded by the A. R. E. A. specifications.

(C) Structural Features of the Code.

Rule 222, Loads Assumed in Determining Stresses in Conductors.—The minimum resultant loading specified is equal to 1.25 times the weight of the conductor. This has the effect for large cables of eliminating the difference between medium and light loadings, so far as the longitudinal stresses are concerned. (See Table 22, page 173.) It is recommended that the rule be changed to make the medium and light loading vary from the heavy loading by varying assumptions of ice and wind. The requirements would be simplified as regards the loading requirements, whether in conductors or supports, for a designated grade of construction, by specifying the same ice and wind loads for the calculation of all stresses. (See also Rule 230.)

Rule 232, Calculation of Loads Upon Line Supports—Section B.—This section should be omitted, since any pole, tower or cross arm should be designed for its loading conditions and not for some average obtained from a group.

Rule 234, Strength of Steel Poles and Towers and Other Metal Supports.—With permissible unit stresses for tension of 27,000 lbs. per sq. in., the shear should be 20,000 lbs., both in structural steel bolts, rivets and pins. The bearing should be made 40,000 lbs., and the bending on bolts or pins, 30,000 lbs. The minimum thickness of metal should be ¼-in. For compression members the 1/r should not exceed 180. With these changes, it will be satisfactory to accept the other provisions of this clause.

Section B. Provision for the combined action of the pole and the guys involves consideration of the deflection of the pole and the accompanying elongation of the guys in order to determine the proportion of the load carried by each. This seems to be inconsistent with Rule 232 (C), which specifies that no allowance shall be made for deflection, deformation, etc. It is suggested that the latter part of Clause B, reading as follows, be omitted:

"When guys are necessarily used, steel supports or towers shall be regarded as taking all of the stress in the direction in which the guys act up to their safe working loads, and the guys shall have sufficient strength to take the remainder of the assumed maximum stresses unless capable of considerable deflection." (See Rule 251d.)

Rule 235, Strength of Wood and Concrete Supports.—The Code permits a factor of safety of 2 for wooden poles and cross arms and reinforced poles and cross arms. The A. R. E. A. specifications require 6 for wood poles and cross arms and 4 for reinforced. The Code permits a minimum top diameter of wooden poles of 7 in., whereas the A. R. E. A. specifications require a minimum of 8 in. The requirements of the A. R. E. A. specifications should not be reduced.

Rule 250, Poles and Towers.—The Code does not require encasing base of wood poles in concrete.

(D) Transmission Crossing Requirements of the Code.

COMPARISON OF THE WIRE CROSSING REQUIREMENTS OF THE NATIONAL ELECTRICAL SAFETY CODE AND THE A. R. E. A. SPECIFICATIONS FOR OVERHEAD CROSSINGS OF ELECTRIC LIGHT AND POWER LINES (ADOPTED 1912).

The tendency of the proposed Code is to reduce the standard requirements of the A. R. E. A. specifications. Specially, 20 of the requirements have been reduced and 27 provisions have been omitted. In general, the proposed Code prescribes less clearance and allows structures of less strength.

The difference in detail is shown in the comparison below:

A. R. E. A. Paragraph	*Safety Code Paragraph*	*Remarks:*
(1)	211	Grade B construction allowed for sidings not exceeding 4 tracks, spurs, branches, or "other unimportant railways."
(2)		Omitted.
(3)		Omitted.
(4)	250d	No change.
(5)		Omitted.
(6)	210b	No change.
(7)		Omitted.
(9)	263 265 240	Where brakemen are permitted on top of standard freight cars, reduces clearances from 30 ft. under most unfavorable conditions of temperature and loading—various clearances of 27 to 30 ft., depending upon voltages and taken at 60 deg. Fahr. instead of unfavorable condition. Where brakemen are not permitted on top of standard freight cars a further reduction to 16 to 22 ft. for various cases.

A. R. E. A. Paragraph	*Safety Code Paragraph*	*Remarks:*
(10)	264 265	Reduces clearances from 8 ft. under most unfavorable condition to 2 ft. to 6 ft. over signal conductors, depending on voltage.
(11)	241 242	Reduces clearances 20 to 40 per cent. Amounts variable depending on size of wire, span, sag and voltage.
(12)	242	Omits mandatory dead-ending and provides additional clearances.
(13)	241 242	Reduces clearances 25 to 50 per cent.
(14)		Omits limitation of change of length in adjoining spans.
(15)	267	Splices and tape permitted in adjoining spans. A "drop out" device permitted to drop the wire (dead) on the railroad in case of breakage.
(16)		Omitted.
(17)	251 233a	Guys on wood poles not required, and even where necessary for strength, need not be placed on the crossing poles if line is straight and full guying is used at points 500 ft. from the crossing poles.
(18)	252	Substantially the same except that voltage limits are made 300 and 15,000.
(19)	250 267	Adds provision against rotten or overhanging tree falling on crossing and adjacent spans.
(20)	205	Guards or signs required outside fenced right of way not required on structures within fenced right of way.
(21)	205c	Omitted (grounding optional).
(22)	93 205c	Reduces minimum ground conductor to No. 6 copper and where other grounds exist on same circuit to No. 10.
(23)	222	Reduces loading condition by raising low temperature from —20 deg. to 0 deg. Fahr.
		In West and part of South the low temperature is made 15 deg., and on the Pacific Coast and the far South it is made 30 deg.
	240	Reduces clearance by using 60 deg. instead of 120 deg. for maximum sag.
(24)		Omitted.
(25)		Omitted.
(26)		Omitted.
(27)	222	In the North and East no change. In the South and West, reduced one-third. In the far South and far West, reduced five-ninths in addition to eliminating ice load.
(28)		Omitted.
(29) (See 16)	231c 233(3b)	Reduces to an ultimate strength to withstand a pull of 700 lbs.

A. R. E. A. Paragraph	*Safety Code Paragraph*	*Remarks:*
(30)	230 232	Increases wind on conductors from 8 lbs. to 12 lbs. for Grade A, North and East.
		Decreases wind on conductors five-ninths, Grade A, far South and West.
(30)	232	For Grade B construction decreased to 7 lbs. for North and East, with other two regions reduced one-third and five-ninths on a 7-lb. base.
		Wind pressure on poles and towers approximately similar to the above changes.
(31)	234f 266a 251	Omitted—no longitudinal strength requirements, except at anchorages of special section of line.
(32)	231 233(3b)	Reduced to a tension of 700 lbs. Indicated that a single wood arm might be allowable.
(33)	266b	Indicated indefinitely.
(34)	233c 231 234 235	Reduces factor of safety to: Wires and Cables..........No change Pine .... 1 Insulators, etc. .... 1 Wood Poles and Arms..... 2 Structural Steel .... 1 Concrete Poles .... 2 Foundations .... 2 Guys 2
		Tables of stresses given for various timbers, etc., which do not agree entirely with the present standard and may or may not agree completely with the above general factor.
		If selected, inspected and maintained to ¾ original strength wood poles may have a factor of 1.25.
(35)	254d	Reduced to about three times normal voltage.
(36)	254c	Test voltage and duration not specified merely a "routine test" or "any other," etc.
(37)	254d 254c	Reduced about 10 to 50 per cent. Duration of test not specified.
(38)	254d	Reduced about 5 to 30 per cent.
(39)		Omitted.
(40)		Omitted.
(41)	221a	Unchanged—in general intent—but not as strongly stated.
(42)	221 233e	No limitation of solid conductors, except that aluminum and "steel reinforced aluminum" shall be stranded.
		Reduced minimum sizes to: No. 6 soft copper. No. 8 hard or medium copper. No. 9 steel.

A. R. E. A. Paragraph	*Safety Code Paragraph*	*Remarks:*
		In urban districts: No. 1 aluminum restricted to 150-ft. spans. No. 0 to be used over 150 ft. Steel reinforced aluminum No. 6 for spans less than 150 ft. and No. 4 for spans over 150 ft.
(43)	254a	Omitted. Allows porcelain or "other material giving equally good results" for voltages over 7500 instead of porcelain at 5000 volts.
(44)	252e	Reduced from twice to a strength equal to the guy.
	252f	No interlocking required.
(45)	231	Omitted.
	234i	Single wooden pins stated as "usually providing strength up to 1000 lbs. tension in conductor 3.5 in. above arm." When steel pins are used the corrosion protection requirement is retained.
	231c	Pins not required to have a strength in excess of 700 lbs. pull.
(46)	234b, i 235a, d 251a, d	No minimum size given.
(47)		Omitted.
(48)		Omitted.
(49)	235c	Reduced from 7-in. top to 6 in. in far West and far South and universally for Grade B construction.
(50)		Omitted.
(51)		Omitted.
(52)		Omitted.
(53)	234c	"Unless similar structures have been tested it is recommended that" 10 per cent. greater strength be used.
(54)	234h	No change.
(55)	234h	Increased from 180 and 220 to "should generally not exceed 150 and 200."
(56)	234h	Reduced from ¼-in. to 3/16-in. for galvanized main members. No change for painted material.
(57)	234i	Galvanizing or painting required, but shop coat is not specified as such.
(58)		Omitted.
(59)		Omitted.
(60)	234d	General recommendations for "a considerable margin of strength."
(61)		Omitted.
(62)		Omitted.
(63)		Omitted.
(64)		Omitted.
(65) (66) (67)	234g 220	Reduced strengths by increasing allowable unit stresses as follows: Structural steel—tension ... 50 per cent. Structural steel—shearing .. 70 per cent.

A. R. E. A. *Paragraph*	*Safety Code* *Paragraph*	*Remarks:*
		Structural steel—compressed 50 per cent.
		Rivets, Pins—shearing ......140 per cent.
		Rivets, Pins—bearing ......140 per cent.
		Rivets, Pins—bending ..... 80 per cent.
		Bolts—shearing ....180 per cent.
		Bolts—bearing ....180 per cent.
		Bolts—bending ....110 per cent.
(68)	Page 172	Practically unchanged when taken in conjunction with par. 34—(223c).
(69)	Page 177	Reduces strengths by increasing allowable unit stresses about 300 per cent.
		No distinction in strength between Chestnut, West Red Cedar, Cypress and Southern Yellow Pine.
Specification for galvanizing		Omitted.

(E) General Conclusions in Regard to the Code.

1. That the general principles of the Code are acceptable and desirable as tending to establish uniform electrical rules in the several States of the Union.

2. That the Code is cumbersome and overburdened with cross references and would be made more useful if separated into several pocket-size pamphlets to cover each of the industries.

3. That the requirements of the Code pertaining to the crossing of railroad company's rights of way by electric cables and wires are deficient and below the specifications of the American Railway Association, the American Railway Engineering Association and the American Electric Railway Association, and should be revised upwards.

4. That the legality of the Code should be established by the opinion of an authority high in the Federal Government.

RECOMMENDATIONS.

1. Your Committee recommends the tentative adoption and publication in the Proceedings of the Electrical Definitions listed in the Report of Sub-Committee No. 1.

2. Acceptance and publication in the Proceedings, as information, the Tabulated Statements Nos. 1 and 2, showing third rail clearances and data relative to overhead clearances on railroads, revised up to November 1, 1917. Continue the subject next year.

3. Acceptance and publication in the Proceedings, as information, the Report of Sub-Committee No. 3, on Catenary Construction.

4. Acceptance and publication in the Proceedings, as information, the Report of Sub-Committee No. 4, on Electrolytic Effect on Concrete in Salt Water, and a continuation of the general subject of Electrolysis, with the sending of authorized representatives to the American Committee on Electrolysis; and asks for further instructions in the matter of a report on Insulation.

5. Acceptance of the progress reports of the Committees on Maintenance Organization, Water Power, and Electrical Interference, with a continuation of these subjects.

6. That the report on the National Electrical Safety Code be accepted and published in the Proceedings, as information, and that the Committee be authorized to send delegates to present a copy of this report to the Director of the U. S. Bureau of Standards, Washington, D. C., and to object to the provisions of the National Electrical Safety Code, which tend to reduce the present requirements of the A. R. E. A. specifications for overhead and underground wire crossings, where the safety of life or property is involved.

7. That the Contract Form on Location of Power Lines and Wires on Railroad Company's Rights of Way be referred to a committee composed of members from the proper standing committees of the American Railway Association and of the American Railway Engineering Association.

Respectfully submitted for the Committee by

Edwin B. Katte, *Chairman.*

REPORT OF COMMITTEE VII—ON WOODEN BRIDGES AND TRESTLES.

E. A. FRINK, *Chairman;*	W. H. HOYT, *Vice-Chairman;*
F. AURYANSEN,	A. O. RIDGWAY,
H. C. BROWN, JR.,	F. S. SCHWINN,
A. D. CASE,	C. S. SHELDON,
A. H. FREYGANG,	I. L. SIMMONS,
E. A. HADLEY,	D. W. SMITH,
F. F. HANLY,	A. M. VANAUKEN,
G. A. HAGGANDER,	W. H. VANCE,
H. T. HAZEN,	D. R. YOUNG,
C. S. HERITAGE,	*Committee.*

To the American Railway Engineering Association:

The following subjects were assigned for the consideration of your Committee during the past year:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

2. Report on design of docks and wharves; coal and ore wharves, including various details, such as bulkheads, cribwork, dry docks, ferry slips, jetties, jetty inclines and the necessary machinery, conveyors and fixtures for the economical operation of property of this character.

3. Report on comparative merits and economic features of ballast deck and reinforced concrete trestles, taking into consideration the design of ballast floors for timber trestles, and collecting data as to costs of various types of each class of structure.

4. Continue the study of the use of lag screws in trestle construction.

In addition, your Committee presents report on Subject (5) of last year, Classification of Wooden Bridges, report on which was not given at the last convention.

The Committee was divided into four Sub-Committees, which have worked during the year on the subjects assigned.

A general meeting was held in the Association's rooms in Chicago on November 24th, at which meeting ten members were present.

A second meeting was held in the Association's rooms on January 19th, 1918, at which nine members were present:

From the work of the Sub-Committee during the year, and after consideration at these meetings, your Committee has compiled the following report:

(1) REVISION OF MANUAL.

In Appendix A the Committee submits its recommendations for changes in the Manual.

(2) DESIGN OF DOCKS AND WHARVES.

Your Committee plans to have prepared standard details of various parts of wharf structures. None of these are yet ready for presentation and the Committee therefore reports progress on this subject.

(3) COMPARATIVE MERITS OF BALLAST DECK AND REINFORCED CONCRETE TRESTLES.

In Appendix B the Committee submits the results of its work on this topic.

(4) USE OF LAG SCREWS IN TRESTLE CONSTRUCTION.

In Appendix C the Committee reports further on this subject, and under the heading of Conclusions makes certain recommendations, which are submitted for adoption and publication in the Manual.

CONCLUSIONS.

1. Your Committee recommends that the changes in the Manual, as given in Appendix A, be adopted.

2. Your Committee recommends that the following conclusions in regard to the use of lag screws in trestle construction be adopted and published in the Manual:

(a) Lag Screws require greater care than ordinary bolts and nuts to properly install, but are cheaper on account of ease of application.

(b) Lag screws, where properly applied, hold ties from bunching equally as well as bolts and nuts, and better than daps, in timber guard rails.

(c) If the lag screws are tightened after timber has shrunk, there is less cost of maintenance than with bolts and nuts.

(d) Use of lag screws renders unnecessary the dumping of guard timbers, and, therefore, decreases cost of trestles without impairing quality.

(e) Surfacing (sizing) ties and guard timbers is better construction than dapping; makes a better riding track, thus decreasing impact stresses, and is therefore good practice.

(f) For proper application of lag screws, holes in guard timbers should be bored with auger bits $\frac{1}{16}$ in. less in diameter than the nominal size of lag screws used.

RECOMMENDATION FOR NEXT YEAR'S WORK.

Your Committee recommends for next year's work the following subjects:

1. Revision of Manual.—Revise the table of recommended stresses on page 244 of the Manual and enlarge it to include stresses in treated timber.

2. Revision of Manual.—Consult with the Committee on Grading of Lumber and prepare changes required to eliminate duplication.

3. Continue study of details of Docks and Wharves.

4. Select the best types of timber trestles and prepare standard details.

Respectfully submitted,

The Committee on Wooden Bridges and Trestles.

Appendix A.

(1) REVISION OF MANUAL.

C. S. Heritage, Chairman, Sub-Committee.

Your Committee recommends the following revisions in the Manual:

(1) In the standard specifications for Southern Yellow Pine bridge and trestle timber, change the heading, "Standard heart grade, longleaf yellow pine," above paragraph No. 4, on page 231, to read, "Standard heart grade, dense yellow pine," and change the heading, "Standard grade, longleaf and shortleaf yellow pine," above paragraph No. 10, on page 232, to read, "Standard grade, sound yellow pine." This is to conform to the classification of yellow pine timber as adopted by the Association in 1916.

(2) That all illustrations, tables and diagrams in the Manual be designated by the number of the page on which they appear, instead of being numbered consecutively, using subscripts when more than one reference appears on any single page.

(3) On page 246, change the last part of paragraph No. 2, "The inner guard rail should not be higher or over one inch lower than the running rail," to read, "* * * should not be higher or more than one inch lower * * *"

(4) On page 232, paragraph No. 9, and on page 241, paragraph No. 26, change the term "guard rails" to "guard timbers" to conform to the definitions given on page 220 and to the use of the term on page 234, paragraph No. 6.

Appendix B.

COMPARATIVE MERITS OF BALLAST AND REINFORCED CONCRETE TRESTLES.

A. O. RIDGWAY, Chairman, Sub-Committee.

All conclusions of the Committee's report of last year were adopted by the Association except one, namely: "Creosoted Timber Trestles are more economical than concrete, except when the cost of the concrete structure is less than one one-half times the cost of the wooden structure."

Upon presentation of the report to the convention considerable discussion occurred, the general purport of which was that this conclusion should be reconsidered by the Committee, principally with respect to the method employed in reaching the results.

Suggestion has been made that the Sinking Fund method is more nearly correct in principle for indicating comparative ultimate economy than the method used by the Committee and heretofore called the "Capitalization Method." Accordingly, much effort and study has during the past year been devoted to the practical effects of the application of the methods to the problem at hand, and the Committee desires to present to the Association the results of its endeavors along this line, both for the specific purpose under discussion and for other purposes of a similar nature.

COMPARISON OF METHODS FOR DETERMINING RELATIVE ECONOMY.

To facilitate ready comparison of the methods to be discussed, the Committee's method, or the "Capitalization Method," used last year, is herein repeated as Analysis No. 1, the Sinking Fund Method as ordinarily used is shown mathematically in Analysis No. 2 and the Replacement Method in Analysis No. 5 in Addenda (1), and for the purpose under consideration they may be defined as follows:

The Replacement Method consists in renewing a structure with new money or with funds taken from operating income. This method is in practically universal use in this country.

The Capitalization Method as used by the Committee is the investment of a fund of such amount and in such manner that the accumulation of interest thereon will periodically amount to a predetermined sum.

The Sinking Fund as used in the Sinking Fund Method employed by this Committee is a fund accumulated by equal periodical increments invested in such manner that at the end of a certain cycle the total will amount to a predetermined sum.

It has heretofore been stated that even though actual installation costs of two structures under comparison are lacking, their relative ultimate economy can be computed as a ratio of the two costs, regardless of the numerical value thereof, which ratio is dependent upon the relative lengths of serviceable life. Or in other words, a ratio of costs depending only upon service life can be determined and which will produce equivalent ultimate economy. These ratios for different combinations of service life are found by substituting for "f" in the Capitalization Method and "F" in the Sinking Fund Method in Analyses Nos. 1 and 2, Addenda (1). Attention is directed to a comparison of the two formulas given in Analysis No. 3, Addenda (1), where the factors involved therein are represented by common symbols. It will be observed from this Analysis No. 3 that the two methods produce identical results, providing a common rate of interest is assumed on capital invested in original cost of structure and on sinking fund annuities. It is the contention of the Committee that this common rate should prevail for the following reasons:

> A distinct loss accrues to an individual in borrowing money for investment in a structure at a rate of interest higher than that carried by money loaned; this is self-evident.
>
> The service use of a structure will undoubtedly return profits in excess of the rate of interest for which money could be borrowed to cover its construction cost, otherwise investment in the structure would not be made. Therefore, capital to cover that cost, whether borrowed or withdrawn from surplus, is worth to the owner at least the price of borrowed money, from which it follows that the acceptance of a lower price for money loaned is an improvident waste.
>
> Since borrowed capital for investment is assumed to return to the investor a greater rate than the cost of borrowing, which assumption must be a fact to insure any investment at all, it would be more profitable for the investor to use all surplus in the expansion of the investment and borrow money for the unimpaired maintenance thereof than to accumulate a surplus to be loaned at a rate of interest below the cost of borrowing, or in other words, the intrinsic worth of all moneys used in the conduct of a business is to the owner equal, at the very least, what it would cost him to borrow.

We, therefore, think a common rate of interest proper and that the assumed rate be taken as the net cost of borrowing, which, as we have previously stated our judgment to indicate 6 per cent. Then, with this common rate of interest the Sinking Fund Method resolves itself automatically into the Capitalization Method used by the Committee and resulting in the basis of the conclusion in question.

For the sake of comparing actual numerical results of the two methods and to show how little divergence really exists in practical effect between them, a statement of ratios of installation costs to produce equivalent ultimate economy computed by the two methods at usual rates of interest and for 20 and 25 years' service lives of timber trestles in contrast to 30 to 100 years' service lives of concrete trestles appears in Addenda (2). Applying the ratios derived by the Sinking Fund Method, results have been obtained for the justifiable expenditures per linear foot for the installation cost of concrete trestles to produce ultimate economy equivalent to that of timber trestles when the latter cost from $10.00 to $20.00 per foot, interest being computed at 6 per cent, and 3 per cent., and at 6 per cent. and 4 per cent. These are shown in the four tabular statements in Addenda (3) and should be compared with the two tabular statements in Appendix A of last year's report, reproduced herewith for convenience in Addenda (4). For example, by the Capitalization Method there would apparently be justification in expending $28.98 for a concrete trestle lasting 100 years when a timber trestle costing $20.00 will last 20 years if interest be reckoned at 6 per cent., while by the Sinking Fund Method, with interest at 6 per cent. and 4 per cent., the justifiable expenditure for the concrete trestle would be $30.78, an amount still consistent with the Committee's general conclusion.

In order to further demonstrate the incorrectness and undesirability of the Sinking Fund Method in its application to matters of this kind, Analysis No. 4, Addenda (1), has been prepared, and shows in detail a comparison of total ultimate costs of the two types of structures as determined by the two methods of providing funds for perpetual maintenance. A study of this analysis shows conclusively the extravagance of the Sinking Fund Method, using lower rates of interest, as compared with the Capitalization Method of providing for the renewal of structures, and proves beyond all doubt that its application to problems of this nature is neither provident nor proper, for it discloses the fact that with a life of the timber trestle fixed at 20 years and with interest at 6 per cent. and 3 per cent., the total ultimate cost of maintenance of structures by the Sinking Fund Method is uniformly 1.115 times that computed by the Capitalization Method, regardless of the period during which the structures are maintained. Thus the Sinking Fund Method in its application to this particular case requires a greater draft on surplus or borrowed capital than the Capitalization Method advocated by the Committee.

A singular, but none the less important and pertinent fact in connection with this particular case, is that in event of an over-estimate in anticipated length of life of the more permanent structure the Sinking Fund Method with lower rates of interest is productive of a greater deficiency in the provision of funds for effecting renewal than is the Capitalization Method. The same line of reasoning may be applied in case length of life is under-estimated, in which event there would be a greater excess of total renewal provision in the form of annuities than if a single sum had been placed at compound interest at date of installation.

To ascertain whether application of the Sinking Fund Method of financing in matters of the kind under discussion is generally used or advocated by railway officers, the Chairman of the Committee sent out one hundred and fifty-four inquiries. Out of a total of one hundred and twenty-two replies, answering for an aggregate of 218,078 miles of line, received thus far, but one, covering a total of 2085 miles, or less than 1 per cent., reports the use of Sinking Fund Method; eight, with a mileage of 13,002, or 6 per cent., while not using it, deem it desirable or have it under consideration; one hundred twenty-one, reporting for a total of 215,993 miles of line, or more than 99 per cent., indicate no actual application whatever. It would seem, therefore, improper to assign any merits to the method on the grounds of widespread favor or extended use as representative of good practice.

From the replies received to the Committee's inquiry, it appears that, with one exception, all roads either (a) set aside a reserve in their working capital to provide for renewals, or else (b) replace structures with money from current funds or money borrowed for the purpose at time the structure needs renewal. Note that (a) is the Sinking Fund Method, with interest return not less than the cost of borrowed money, which method has been heretofore shown to be identical in ultimate cost with the Capitalization Method (see Addenda (1), Analysis 3), while (b) is the method in most general use and is herein called the Replacement Method. Computing the total cost by the Replacement Method, it also is found to be identical with the Capitalization Method. This is clearly demonstrated in Addenda (1), Analysis 5.

It appears, therefore, that the Capitalization Method proposed by this Committee is virtually in use to-day by practically all roads.

First.—The Sinking Fund Method is identical with Capitalization Method when interest rate on annuities is same as interest rate on original investment cost, which equality of interest rate is logical, desirable and imperative for the conservation of finance.

Second.—There is not only improvidence but extravagance in the use of the Sinking Fund Method with lower rate of interest in financing the recurring renewals of perishable structures.

Third.—Wider departure between actual monetary demands and available financial provision therefore occurs with the Sinking Fund Method, as compared with the Capitalization Method, if an error has been made in expected length of life.

Fourth.—That the Sinking Fund Method, by reason of its extended use and general favor, should be adopted in comparing ultimate economy of railway structures is entirely unwarranted.

Fifth.—The Sinking Fund Method is cumbersome, complex, and difficult of strict application in practical use, while the Capitalization Method is relatively simple and meets with equity every requirement necessary for comparative purposes.

Sixth.—The Capitalization Method is virtually the only method in use to-day.

CURRENT MAINTENANCE AND INSPECTION.

As the Committee has heretofore pointed out, it is impossible to secure reliable figures for the cost of repairs to keep in serviceable condition throughout their lifetime ballast deck creosoted trestles, principally because no record thereof has been kept for sufficiently long periods to establish any basis for computation. No additional data of value for this factor of the case could be collected during the year. With respect to extra cost of maintenance of way and structures, due to keeping free from dry grass, weeds or other inflammable debris the right-of-way at the bridge site, the Committee has already expressed its judgment that such service should be equally well performed whether the trestle is a concrete or wooden structure, and, therefore, should be neglected in a comparison of the two types. This opinion is based on very obvious requirements of eliminating hazard of fire damage to contiguous property, both of railway and others, and of general neatness and thrift. Finally, we may add with propriety, that concrete structure will not be entirely free from charges for maintenance and inspection.

Insurance.

Attention is directed to the Committee's discussion of "Fire Hazard" in the report of last year, to the effect that there is little probability of fire loss in the ballast deck timber trestle. During the year inquiries have been sent out to the larger railways of the United States and Canada, in an endeavor to ascertain current practice with respect to whether insurance is placed on either open deck or ballasted deck timber trestles, and if so, whether a difference in percentage of value for which the two types of wooden trestles are insured prevails. Out of a total of 157,673 miles of line reporting, 69,039 miles, or 43.8 per cent., carried no insurance on such structures; 28,623 miles, or 18.2 per cent., maintain their own insurance fund; 60,011 miles, or 38 per cent., insure with outside companies. While generally it seems to be the practice of roads using both open deck and ballasted deck trestles not to differentiate between the two kinds, either in percentage of value insured or rates paid therefor, we find there is so great a divergence in such rates paid by the several lines that no general rule is applicable. It is evident, however, that with the prevalent low insurance rates and drafts, inconsiderable in magnitude and infrequent in occurrence, on company insurance funds, we are not justified in introducing into the question of ultimate economy any numerical value for a factor of so uncertain and elusive a character. It seems to us far better to point out the probable degree of fire hazard to be considered in the adoption of type rather than to attempt the assignment of what must necessarily be a speculative monetary value thereto, and this course has been followed.

CONCLUSIONS.

Attention is invited to the Committee's recommended disposition of its report of last year of all these uncertain and indeterminate factors, which were mentioned in detail, and we beg to submit briefly a repetition of such recommendation, based on the following considerations:

First.—The Capitalization Method properly shows the relative worth of the capital invested in structures of different serviceable lives and is, therefore, a desirable criterion for comparing ultimate economy.

Second.—In the absence of authentic data as to cost of current maintenance, inspection, insurance and uncertain renewal cost of both or either of two types of structures, the annual expense of upkeep should evidently be omitted in any comparative statement of cost, leaving the relative influence thereof to be considered by the investigator.

The Committee has been guided by these two principles in reporting its conclusions—the first in using the Capitalization Method for indicating the justifiable expenditure in installation costs of concrete trestles to produce ultimate economy equivalent to various installation costs of creosoted timber trestles, and the second in its suggestion as to assumed life of the timber structure to be used as the argument, for notwithstanding practical unanimity of best authorities in that the creosoted structure will last twenty-five years, it has recommended to the Association the use of a twenty-year life in considering economic value. This arbitrary reduction in assumed life of timber trestle we think ample to compensate for the indeterminate elements and consider further refinement totally unnecessary, especially since there is likely to be a difference of opinion, even to the extent of 100 per cent., in the assumption as to the probable life of the concrete.

We, therefore, believe Conclusion No. 6 of last year's report wholly warranted, and, after thorough reconsideration, again recommend its adoption for printing in the Manual in the order and substance as therein stated: "Creosoted timber trestles are more economical than concrete, except when the cost of the concrete structure is less than one and one-half times the cost of the wooden structure."

A recommendation is also made for the adoption by the Association for printing in the Manual the formula for the Capitalization Method as developed in Analysis No. 1, Addenda (1), and its accompanying tabular statements, Nos. 1 and 2, in Addenda (4) hereof.

In order that the members may also have at hand for convenience in any purpose for which applicable all the results of the Committee's work, it is further recommended that the statement of ratios of installation costs developed by the Capitalization Method and appearing in Addenda (5) be adopted and printed in the Manual.

Addenda (1)—Analysis No. 1.

CAPITALIZATION METHOD

COMPARATIVE ECONOMIC VALUE
BALLAST DECK TRESTLES

w = Cost of Wooden Trestle.
c = Cost of Concrete Trestle.
r = Rate of interest.
m = Life in years of wooden trestle.
n = " " " " concrete "
x = Amount capitalized which will replace wooden trestle every m years.
y = " " " " " concrete " " n "
f = Ratio of first cost of concrete trestle to first cost of wooden trestle to produce equal ultimate economy, that is
$f = \frac{c}{w}$ or $fw = c$

Then $x(1+r)^m = w + x$ and $y(1+r)^n = c + y$, whence $x = \frac{w}{[(1+r)^m - 1]}$

and $y = \frac{c}{[(1+r)^n - 1]} = \frac{fw}{[(1+r)^n - 1]}$

To produce equivalent ultimate economy $w + x = c + y$, which by substituting values of x and y gives

$$w + \frac{w}{[(1+r)^m - 1]} = fw + \frac{fw}{[(1+r)^n - 1]}$$

Dividing by w and solving for f it is found that

$$f = \frac{1 + \frac{1}{[(1+r)^m - 1]}}{1 + \frac{1}{[(1+r)^n - 1]}}$$

which is variable only with respect to m and n the assumed lives of wood and concrete. By using as an argument first cost of wooden trestle with a constant life regardless of such cost, the first cost of a concrete trestle with a life of n years is found by applying to cost of wooden trestle the coefficient f determined for n years.

Addenda (1)—Analysis No. 2.

SINKING FUND METHOD

COMPARATIVE ECONOMIC VALUE
BALLAST DECK TRESTLES

W = Cost of Wooden Trestle.
C = Cost of Concrete Trestle.
r = Rate of Interest on Cost of Trestle.
r' = " " " earned by Sinking Fund.
m = Life, in years, of Wooden Trestle.
n = " " " " Concrete "
a = Annual Contribution to Sinking Fund required to reproduce wooden trestle at end of m years.
b = Wr = Annual interest on original cost of Wooden Trestle.
d = Annual Contribution to Sinking Fund required to reproduce concrete trestle at end of n years.
e = Cr = Annual interest on original cost of Concrete Trestle.
E = $a+b$ = Annual expense of wooden trestle.
E = $d+e$ = " " " concrete " .
F = Ratio of first cost of concrete trestle to first cost of wooden trestle to produce equal ultimate economy; that is
$F = \frac{C}{W}$ or $FW = C$

Then $E = Wr + \frac{W}{(1+r')^{m-1} + (1+r')^{m-2} \ldots\ldots + 1}$

and $E' = Cr + \frac{C}{(1+r')^{n-1} + (1+r')^{n-2} \ldots\ldots + 1}$

To produce equal economy $E = E'$ and by substituting values of E, E' and C and solving for F.

$$F = \frac{r + \frac{1}{(1+r')^{m-1} + (1+r')^{m-2} + 1}}{r + \frac{1}{(1+r')^{n-1} + (1+r')^{n-2} + 1}} = \frac{r + \frac{}{\frac{(1+r')^{m} - 1}{(1+r') - 1}}}{r + \frac{1}{\frac{(1+r')^{n} - 1}{(1+r') - 1}}} = \frac{r + \frac{r'}{(1-r')^{m} - 1}}{r + \frac{r'}{(1+r')^{n} - 1}}$$

Addenda (1)—Analysis No. 3.

COMPARISON OF METHODS

COMPARATIVE ECONOMIC VALUE BALLAST DECK TRESTLES

W = Cost of Wooden Trestle.
C = Cost of Concrete Trestle.
r = Rate of Interest on Cost of Trestle.
r' = " " " earned by Sinking Fund.
m = Life, in years, of Wooden Trestle.
n = " " " " Concrete Trestle.
f = Ratio of first cost of Concrete Trestle to first cost of Wooden Trestle to produce equal ultimate economy by capitalization method, that is

$$f = \frac{C}{W} \text{ or } fW = C$$

F = Ratio of first cost of Concrete Trestle to first cost of Wooden Trestle to produce equal ultimate economy by sinking fund method, that is

$$F = \frac{C}{W} \text{ or } FW = C$$

By capitalization method $$f = \frac{1 + \frac{1}{(1+r)^m - 1}}{1 + \frac{1}{(1+r)^n - 1}} \qquad (1)$$

By sinking fund method $$F = \frac{r + \frac{r'}{(1+r')^m - 1}}{r + \frac{r'}{(1+r')^n - 1}} \qquad (2)$$

A comparison shows the two methods to be identical if same rate of interest is earned on sinking fund as that paid on cost of trestle, for in that case $r' = r$ and by substituting r for r' in (2) it becomes

$$F = \frac{1 + \frac{1}{(1+r)^m - 1}}{1 + \frac{1}{(1+r)^n - 1}} \qquad (3)$$

which is identical with (1) and $f = F$ It is therefore evident that regardless of what rate of interest is used the two methods are productive of the same results provided only that the same rate of interest be applied to sinking fund as to original cost of trestle.

Addenda (1)—Analysis No. 4.

COMPARISON OF ULTIMATE TOTAL COST OF BALLAST DECK TRESTLES WITH FUNDS FOR RENEWALS PROVIDED BY CAPITALIZATION AND SINKING FUND METHODS

w = Cost of Wooden Trestle.
c = " " Concrete "
r = Rate of Interest.
r' = " " " earned by Sinking Fund.
m = Life in years of Wooden Trestle.
n = " " " " Concrete "
w' = Ultimate total cost of Wooden Trestle for n years (Capitalization Method)
w'' = " " " " " " " n " (Sinking Fund Method, rate of interest = r)
w''' = " " " " " " " n " (" " " " " " = r')
c' = " " " " Concrete " " n " (Capitalization Method)
c'' = " " " " " " " n " (Sinking Fund Method, rate of interest = r)
c''' = " " " " " " " n " (" " " " " " = r')
x = Amount capitalized which will replace Wooden Trestle every m years.
y = " " " " " Concrete " " n " .
a = Annual Sinking Fund Payments required to produce \$1.00 in m years at r interest
a' = " " " " " " " \$1.00 " m " " r' "
d = " " " " " " " \$1.00 " n " " r "
d' = " " " " " " " \$1.00 " n " " r' "

BY CAPITALIZATION METHOD

$$w' = w(1+r)^n - w + x(1+r)^n - x \quad \text{and} \quad x = w\frac{1}{(1+r)^m-1} \quad \text{then}$$

$$w' = w(1+r)^n - w + w\frac{1}{(1+r)^m-1}\left[(1+r)^n-1\right] = w\left[(1+r)^n - 1 + \frac{(1+r)^n-1}{(1+r)^m-1}\right]$$

$$c' = c(1+r)^n - c + y(1+r)^n - y \quad \text{and} \quad y = c\frac{1}{(1+r)^n-1} \quad \text{then}$$

$$c' = c(1+r)^n - c + c\frac{1}{(1+r)^n-1}\left[(1+r)^n-1\right] = c(1+r)^n$$

BY SINKING FUND METHOD WHEN RATE OF INTEREST ON SINKING FUND IS r

$$w'' = w(1+r)^n - w + wa\frac{(1+r)^n-1}{r} \quad \text{and} \quad a = \frac{r}{(1+r)^m-1} \quad \text{then}$$

$$w'' = w(1+r)^n - w + w\frac{r}{(1+r)^m-1}\cdot\frac{(1+r)^n-1}{r} = w\left[(1+r)^n - 1 + \frac{(1+r)^n-1}{(1+r)^m-1}\right]$$

$$c'' = c(1+r)^n - c + cd\frac{(1+r)^n-1}{r} \quad \text{and} \quad d = \frac{r}{(1+r)^n-1} \quad \text{then}$$

$$c'' = c(1+r)^n - c + c\frac{r}{(1+r)^n-1}\cdot\frac{(1+r)^n-1}{r} = c(1+r)^n$$

BY SINKING FUND METHOD WHEN RATE OF INTEREST ON SINKING FUND IS r'

$$w''' = w(1+r)^n - w + wa'\frac{(1+r)^n-1}{r} \quad \text{and} \quad a' = \frac{r'}{(1+r')^m-1} \quad \text{then}$$

$$w''' = w(1+r)^n - w + w\frac{r}{(1+r')^m-1}\cdot\frac{(1+r)^n-1}{r} = w\left[(1+r)^n - 1 + \frac{r'(1+r)^n - r'}{r(1+r')^m - r}\right]$$

$$c''' = c(1+r)^n - c + cd'\frac{(1+r)^n-1}{r} \quad \text{and} \quad d' = \frac{r'}{(1+r')^n-1} \quad \text{then}$$

$$c''' = c(1+r)^n - c + c\frac{r'}{(1+r')^n-1}\cdot\frac{(1+r)^n-1}{r} = c\left[(1+r)^n - 1 + \frac{r'(1+r)^n - r'}{r(1+r')^n - r}\right]$$

From the above results it will be seen that the ultimate total cost of any trestle will be the same when funds for renewals are provided by Capitalization Method, as when provided by Sinking Fund Method, if the rate of interest on Sinking Fund equals the rate of interest on first cost.

Now let F' = the ratio between the Ultimate Cost of any trestle when funds for renewals are provided by Sinking Fund and Capitalization Methods: Interest on Sinking Fund = r'

$$F' = \frac{w'''}{w'} = \frac{w\left[(1+r)^n - 1 + \frac{r'(1+r)^n - r'}{r(1+r')^n - r}\right]}{w\left[(1+r)^n - 1 + \frac{(1+r)^n-1}{(1+r)^m-1}\right]} = \frac{1 + \frac{r'}{r(1+r')^m - r}}{1 + \frac{1}{(1+r)^m-1}}$$

WHEN $m = 20$, $r = .06$, AND $r' = .03$, THEN $F' = 1.115$

TABLE GIVING ULTIMATE TOTAL COST OF TRESTLES BY CAPITALIZATION AND SINKING FUND METHODS

BASED ON 20 YEAR LIFE AND FIRST COST UNITY, WITH 6% INTEREST ON FIRST COST, AND 3% INTEREST ON SINKING FUND

METHODS	ULTIMATE TOTAL COST OF A CREOSOTED TIMBER OR CONCRETE TRESTLE FOR FOLLOWING PERIODS IN YEARS								
	20	30	40	50	60	70	80	90	100
CAPITALIZATION METHOD	3.207	6.892	13.49	25.31	46.48	84.39	152.28	273.86	491.59
SINKING FUND METHOD	3.576	7.685	15.05	28.22	51.83	94.10	169.79	305.36	548.15

NOTE:– Above values show the ratio F' to be uniformly 1.115 for all periods considered.

Addenda (1)—Analysis No. 5.

REPLACEMENT METHOD
COMPARATIVE ECONOMIC VALUE
BALLAST DECK TRESTLES

w = Cost of Wooden Trestle.
c = " " Concrete "
r = Rate of Interest
m = Life in years of Wooden Trestle.
n = " " " " Concrete "
A = Cost of Wooden Trestle for a period of n years.
B = " " Concrete " " " " " n "
f' = Ratio of first cost of concrete trestle to first cost of wooden trestle to produce equal ultimate economy, that is

$f' = \frac{c}{w}$ or $f'w = c$

Then $A = w\left[(1+r)^m + (1+r)^{2m} \ldots\ldots + (1+r)^{n-2m} + (1+r)^{n-m} + (1+r)^n\right] = w\frac{(1+r)^{n+m} - (1+r)^m}{(1+r)^m - 1}$

and $B = c(1+r)^n$

To produce equivalent ultimate economy $A = B$, which by substituting values of A, B and c gives

$$f'w(1+r)^n = w\frac{(1+r)^{n+m} - (1+r)^m}{(1+r)^m - 1}$$

Dividing by w and solving for f' it is found that

$$f' = \frac{\frac{(1+r)^{n+m} - (1+r)^m}{(1+r)^m - 1}}{(1+r)^n} = \frac{(1+r)^{n+m} - (1+r)^m}{(1+r)^{n+m} - (1+r)^n} = \frac{\frac{(1+r)^{n+m} - (1+r)^m}{\left[(1+r)^n - 1\right]\left[(1+r)^m - 1\right]}}{\frac{(1+r)^{n+m} - (1+r)^n}{\left[(1+r)^n - 1\right]\left[(1+r)^m - 1\right]}}$$

$$= \frac{\frac{(1+r)^m}{(1+r)^m - 1}}{\frac{(1+r)^n}{(1+r)^n - 1}} = \frac{1 + \frac{1}{(1+r)^m - 1}}{1 + \frac{1}{(1+r)^n - 1}}$$

which is identical to the value of f in the Capitalization Method.

Addenda (2).

A COMPARISON OF RATIOS OF INSTALLATION COSTS OF BALLAST DECK TRESTLES TO PRODUCE EQUIVALENT ULTIMATE ECONOMY BASED ON TWO METHODS OF COMPUTATION.

	20 YEAR LIFE FOR TIMBER				25 YEAR LIFE FOR TIMBER			
	SINKING FUND METHOD		CAPITALIZATION METHOD		SINKING FUND METHOD		CAPITALIZATION METHOD	
LIFE OF CONCRETE YEARS	Interest at 6% and 3%	Interest at 6% and 4%	Interest at 5%	Interest at 6%	Interest at 6% and 3%	Interest at 6% and 4%	Interest at 5%	Interest at 6%
30	1.200	1.202	1.244	1.200	1.079	1.079	1.091	1.077
40	1.326	1.327	1.389	1.309	1.193	1.191	1.218	1.174
50	1.411	1.406	1.478	1.374	1.268	1.262	1.295	1.233
60	1.473	1.458	1.532	1.409	1.322	1.309	1.345	1.264
70	1.512	1.491	1.566	1.428	1.359	1.339	1.372	1.282
80	1.540	1.514	1.586	1.439	1.385	1.359	1.390	1.291
90	1.561	1.529	1.599	1.446	1.404	1.376	1.401	1.297
100	1.578	1.539	1.607	1.449	1.419	1.382	1.408	1.300

Addenda (3).

COMPARATIVE COST OF INSTALLATION OF BALLAST DECK TRESTLES PER LINEAR FOOT TO PRODUCE EQUIVALENT ECONOMIC VALUE; SINKING FUND METHOD; INTEREST ON ORIGINAL COST AT 6 PER CENT. PER ANNUM; AND INTEREST ON SINKING FUND FOR MAINTENANCE AT 3 PER CENT. PER ANNUM. ASSUMING CREOSOTED TRESTLE WILL LAST 20 YEARS.

CREOSOTED TIMBER SERVICE LIFE 20 YEARS	JUSTIFIABLE EXPENDITURE FOR CONCRETE SERVICEABLE FOR							
	30 Yrs.	40 Yrs.	50 Yrs.	60 Yrs.	70 Yrs.	80 Yrs.	90 Yrs.	100 Yrs.
$10.00	$12.00	$13.26	$14.11	$14.73	$15.12	$15.40	$15.61	$15.78
11.00	13.20	14.59	15.52	16.20	16.63	16.94	17.17	17.36
12.00	14.40	15.91	16.93	17.68	18.14	18.48	18.73	18.94
13.00	15.60	17.24	18.34	19.15	19.66	20.02	20.29	20.51
14.00	16.80	18.56	19.75	20.62	21.17	21.56	21.85	22.09
15.00	18.00	19.89	21.17	22.10	22.68	23.10	23.42	23.67
16.00	19.20	21.22	22.58	23.57	24.19	24.64	24.98	25.25
17.00	20.40	22.54	23.99	25.04	25.70	26.18	26.54	26.83
18.00	21.60	23.87	25.40	26.51	27.22	27.72	28.10	28.40
19.00	22.80	25.19	26.81	27.99	28.73	29.26	29.60	29.98
20.00	24.00	26.52	28.22	29.46	30.24	30.80	31.22	31.56

Addenda (3)—Continued.

COMPARATIVE COST OF INSTALLATION PER LINEAR FOOT TO PRODUCE EQUIVALENT ECONOMIC VALUE; SINKING FUND METHOD; INTEREST ON ORIGINAL COST AT 6 PER CENT. PER ANNUM AND INTEREST ON SINKING FUND FOR MAINTENANCE AT 3 PER CENT. PER ANNUM. ASSUMING CREOSOTED TRESTLE WILL LAST 25 YEARS.

CREOSOTED TIMBER SERVICE LIFE 25 YEARS	JUSTIFIABLE EXPENDITURE FOR CONCRETE SERVICEABLE FOR							
	30 Yrs.	40 Yrs.	50 Yrs.	60 Yrs.	70 Yrs.	80 Yrs.	90 Yrs.	100 Yrs
$10.00	$10.79	$11.92	$12.68	$13.22	$13.59	$13.85	$14.04	$14.19
11.00	11.87	13.11	13.95	14.54	14.95	15.24	15.44	15.61
12.00	12.95	14.30	15.22	15.86	16.31	16.62	16.85	17.03
13.00	14.03	15.50	16.48	17.19	17.67	18.01	18.25	18.45
14.00	15.11	16.69	17.75	18.51	19.03	19.39	19.66	19.87
15.00	16.19	17.88	19.02	19.83	20.39	20.78	21.06	21.29
16.00	17.26	19.07	20.29	21.15	21.74	22.16	22.46	22.70
17.00	18.34	20.26	21.56	22.47	23.10	23.55	23.87	24.12
18.00	19.42	21.46	22.82	23.80	24.46	24.93	25.27	25.54
19.00	20.50	22.65	24.09	25.12	25.82	26.32	26.68	26.96
20.00	21.58	23.84	25.36	26.44	27.18	27.70	28.08	28.38

Addenda (3)—Continued.

COMPARATIVE COST OF INSTALLATION OF BALLAST DECK TRESTLES PER LINEAR FOOT TO PRODUCE EQUIVALENT ECONOMICAL VALUE; SINKING FUND METHOD; INTEREST ON ORIGINAL COST AT 6 PER CENT. PER ANNUM AND INTEREST ON SINKING FUND FOR MAINTENANCE AT 4 PER CENT. PER ANNUM. ASSUMING CREOSOTED TRESTLE WILL LAST 20 YEARS.

CREOSOTED TIMBER SERVICE LIFE 20 YEARS	JUSTIFIABLE EXPENDITURE FOR CONCRETE SERVICEABLE FOR							
	30 Yrs.	40 Yrs.	50 Yrs.	60 Yrs.	70 Yrs.	80 Yrs.	90 Yrs.	100 Yrs.
$10.00	$12.02	$13.27	$14.06	$14.58	$14.91	$15.14	$15.29	$15.39
11.00	13.23	14.60	15.47	16.03	16.41	16.65	16.82	16.93
12.00	14.43	15.92	16.87	17.49	17.90	18.17	18.35	18.47
13.00	15.63	17.25	18.28	18.95	19.39	19.68	19.88	20.01
14.00	16.83	18.58	19.69	20.41	20.88	21.19	21.40	21.54
15.00	18.04	19.90	21.09	21.86	22.37	22.70	22.93	23.08
16.00	19.24	21.23	22.50	23.32	23.86	24.22	24.46	24.62
17.00	20.44	22.56	23.91	24.78	25.35	25.74	25.99	26.16
18.00	21.64	23.89	25.31	26.24	26.85	27.25	27.52	27.70
19.00	22.85	25.21	26.72	27.69	28.34	28.76	29.05	29.24
20.00	24.05	26.54	28.12	29.10	29.82	30.28	30.58	30.78

Addenda (3)—Continued.

COMPARATIVE COST OF INSTALLATION OF BALLAST DECK TRESTLES PER LINEAR FOOT TO PRODUCE EQUIVALENT ECONOMIC VALUE; SINKING FUND METHOD; INTEREST ON ORIGINAL COST AT 6 PER CENT. PER ANNUM; AND INTEREST ON SINKING FUND FOR MAINTENANCE AT 4 PER CENT. PER ANNUM. ASSUMING CREOSOTED TRESTLE WILL LAST 25 YEARS.

CREOSOTED TIMBER SERVICE LIFE 25 YEARS	JUSTIFIABLE EXPENDITURE FOR CONCRETE SERVICEABLE FOR							
	30 Yrs.	40 Yrs.	50 Yrs.	60 Yrs.	70 Yrs.	80 Yrs.	90 Yrs.	100 Yrs
$10.00	$10.79	$11.91	$12.62	$13.09	$13.39	$13.59	$13.76	$13.82
11.00	11.87	13.10	13.89	14.39	14.73	14.95	15.13	15.20
12.00	12.95	14.30	15.15	15.70	16.07	16.31	16.51	16.58
13.00	14.03	15.49	16.41	17.01	17.41	17.61	17.88	17.96
14.00	15.11	16.68	17.67	18.32	18.75	19.03	19.26	19.34
15.00	16.19	17.87	18.94	19.63	20.08	20.39	20.64	20.72
16.00	17.27	19.06	20.20	20.94	21.42	21.75	22.01	22.10
17.00	18.35	20.25	21.46	22.25	22.76	23.10	23.39	23.49
18.00	19.43	21.44	22.72	23.55	24.10	24.46	24.76	24.87
19.00	20.51	22.63	23.99	24.86	25.44	25.82	26.14	26.25
20.00	21.59	23.83	25.25	26.17	26.78	27.18	27.51	27.63

Addenda (4).

COMPARATIVE COST OF INSTALLATION OF BALLAST DECK TRESTLES PER LINEAR FOOT TO PRODUCE EQUIVALENT ECONOMIC VALUE; INTEREST AT 6 PER CENT. PER ANNUM. ASSUMING CREOSOTED TIMBER TRESTLE WILL SERVE 20 YEARS.

CREOSOTED TIMBER SERVICE LIFE 20 YEARS	JUSTIFIABLE EXPENDITURE FOR CONCRETE SERVICEABLE FOR							
	30 Yrs	40 Yrs	50 Yrs	60 Yrs	70 Yrs	80 Yrs	90 Yrs	100 Yrs
$10 00	$12 00	$13 09	$13 74	$14 09	$14 28	$14 39	$14 46	$14 49
11 00	13 20	14 39	15 12	15 50	15 71	15 83	15 90	15 94
12 00	14 40	15 70	16 49	16 91	17 14	17 26	17 35	17 39
13 00	15 60	17 01	17 86	18 32	18 57	18 70	18 79	18 83
14 00	16 80	18 32	19 24	19 73	20 00	20 14	20 24	20 28
15 00	18 00	19 63	20 61	21 14	21 43	21 58	21 68	21 73
16 00	19 20	20 94	21 99	22 54	22 86	23 02	23 13	23 18
17 00	20 40	22 24	23 36	23 95	24 28	24 46	24 57	24 63
18 00	21 60	23 55	24 74	25 36	25 71	25 90	26 02	26 09
19 00	22 80	24 86	26 11	26 77	27 14	27 34	27 46	27 53
20 00	24 00	26 17	27 48	28 18	28 57	28 77	28 91	28 98

Addenda (4).

COMPARATIVE COST OF INSTALLATION OF BALLAST DECK TRESTLES PER LINEAR FOOT TO PRODUCE EQUIVALENT ECONOMIC VALUE; INTEREST AT 6 PER CENT. PER ANNUM. ASSUMING CREOSOTED TIMBER TRESTLE WILL SERVE 25 YEARS.

CREOSOTED TIMBER SERVICE LIFE 25 YEARS	JUSTIFIABLE EXPENDITURE FOR CONCRETE SERVICEABLE FOR							
	30 Yrs	40 Yrs	50 Yrs	60 Yrs	70 Yrs	80 Yrs	90 Yrs	100 Yrs
$10 00	$ 10 77	$11 74	$12 33	$12 64	$12 82	$12 91	$12 97	$13 00
11 00	11 84	12 91	13 56	13 91	14 10	14 20	14 27	14 30
12 00	12 92	14 09	14 80	15 17	15 38	15 49	15 56	15 60
13 00	14 00	15 26	16 03	16 44	16 66	16 78	16 86	16 90
14 00	15 07	16 44	17 26	17 70	17 94	18 07	18 16	18 20
15 00	16 15	17 61	18 50	18 96	19 23	19 36	19 45	19 50
16 00	17 23	18 79	19 73	20 23	20 51	20 65	20 75	20 80
17 00	18 31	19 96	20 96	21 49	21 79	21 94	22 05	22 10
18 00	19 38	21 13	22 19	22 76	23 07	23 24	23 34	23 40
19 00	20 46	22 31	23 43	24 02	24 35	24 53	24 64	24 70
20 00	21 54	23 48	24 66	25 29	25 63	25 82	25 94	26 00

Addenda (5).

RATIO OF INSTALLATION COSTS OF STRUCTURES TO PRODUCE EQUIVALENT ULTIMATE ECONOMY IN THEIR PERPETUAL MAINTENANCE. BASED ON AN INTEREST RATE OF 6 PER CENT. PER ANNUM FOR CAPITAL INVESTED THEREIN, AND NEGLECTING COSTS OF REPAIRS.

SERVICE LIFE YEARS	5	10	15	20	25	30	40	50	60	70	80	90	100
100	3.94491	2.25779	1.71099	1.44880	1.29994	1.20725	1.10721	1.05429	1.02822	1.01422	1.00702	1.00234	1.00000
90	3.93569	2.25251	1.70699	1.44551	1.29690	1.20442	1.10462	1.05182	1.02582	1.01185	1.00467	1.00000	
80	3.91741	2.24205	1.69906	1.43669	1.29087	1.19883	1.09949	1.04694	1.02105	1.00715	1.00000		
70	3.88960	2.22618	1.68700	1.42848	1.28171	1.19032	1.09168	1.03951	1.01380	1.00000			
60	3.83663	2.19582	1.66403	1.40903	1.26426	1.17411	1.07682	1.02771	1.00000				
50	3.74177	2.14153	1.62288	1.37419	1.23300	1.14508	1.05019	1.00000					
40	3.56295	2.03918	1.54532	1.30852	1.17407	1.09035	1.00000						
30	3.26770	1.87020	1.41727	1.20008	1.07678	1.00000							
25	3.03470	1.73684	1.31621	1.11451	1.00000								
20	2.72290	1.55840	1.18098	1.00000									
15	2.30564	1.31958	1.00000										
10	1.74725	1.00000											
5	1.00000												

This statement is developed from formula in Addenda (1), Analysis No. 1.

Appendix C.

(4) USE OF LAG SCREWS IN TRESTLE CONSTRUCTION.

D. W. Smith, Chairman, Sub-Committee.

The uses to which lag screws have been put in railroad maintenance and construction have been both varied and of long duration. The investigation of this Committee in regard to lag screws has been restricted to only one of the many uses, viz., their relative merit compared with bolts in fastening guard timbers to ties on wooden bridges and trestles. On many of our railroads lags have been used quite extensively for this purpose, and in several instances have become the standard of the road. Frequently they have been used in connection with bolts alternately in every second or third tie.

No standard or uniform method seems to exist as to their type or use. Where lags have not given satisfaction, it can generally be traced to improper method of use. In some cases the lags used were too small to withstand the strain put upon them. Some have improperly applied them by using them in a hole bored too large or too small or perhaps too shallow. Failure can occasionally be attributed to the method of application where the lag is driven with a sledge, thus crushing the wood fiber and rendering it useless. In such cases water enters the timber around the lag and in a short time decay sets in and loose lags are the result. To obtain the greatest efficiency the hole should be bored to proper size and depth, so that when the lag is screwed to its full depth the hole will be entirely filled.

For several years the Committee has had the subject of lag screws under investigation. A careful comparison of the best methods of application has been made the subject of careful study. Early in 1914 various inquiries were sent to a large number of carriers throughout the country, outlining to them the desire of the Committee and requesting certain information to enable it to further study the merits of lags. The constant aim of the Committee has been to locate the source of trouble where lags had been in use, and later discarded on account of not meeting requirements.

A study of the one hundred and thirty-one replies received to inquiries of the Committee, aggregating 203,000 miles of railway, showed that 103 roads, with a combined mileage of 159,000 miles, never used lag screws in any form. Twenty-eight roads, with a combined mileage of 44,000 miles, had used them in some form or other with varied success.

To formulate a more conclusive comparison, another circular was sent to such carriers as had not yet used lags to induce them to make a test along lines outlined by the Committee. Of the seventy-five replies received in answer to this circular, 37 roads, with a combined mileage of 74,000 miles, indicated their willingness to make a test of lag screws along such lines and under such instructions as the Committee might direct. A plan was prepared illustrating the recommendations of the Committee. On this same plan there were shown designs illustrating the practice of a few of the roads relative to their method of use of lags. This plan was sent to each of the 37 roads previously expressing its willingness to give lags a trial on one or more structures on the line of its road. To this request, 17 roads, with a combined mileage of 39,600, complied and reported the results of their test to the Committee. Only two of these roads reported in any way adversely, while the large majority of them were convinced that lags had certain advantageous features not common to bolts.

The principal features of the test, as recommended by the Committee, are the elimination of the dapping of guard timbers and ties, and the use of lags in each tie with a drift bolt in each second tie to securely fasten the tie to the stringer, as illustrated in (Fig. 1).

It is also evident from an examination of the plan that the lining of the track on the stringers is materially simplified, since there is no dapping of ties over stringers to interfere.

Where the suggestions of the Committee were followed in the test almost universal satisfaction was obtained. Although comparatively few roads have used the design of trestle shown in Fig. 1, yet since those who have used it are thoroughly satisfied, the Committee feels free in recommending its use as a safe and economical form of construction. In corroboration of the above, the following is an extract from a report of one of the carriers making the test, and clearly sets forth the merits of lag screws when compared with bolts and nuts under similar conditions on the same structure:

"1. Size of lag screw, ¾ in. by 8 in.

"2. Lag screws were placed in each end of each tie.

"3. Ties were dapped a varying amount, from 0 in. to ½ in., to provide a true surface for the rails. The wooden guard rails were not dapped, but laid flat on the ties.

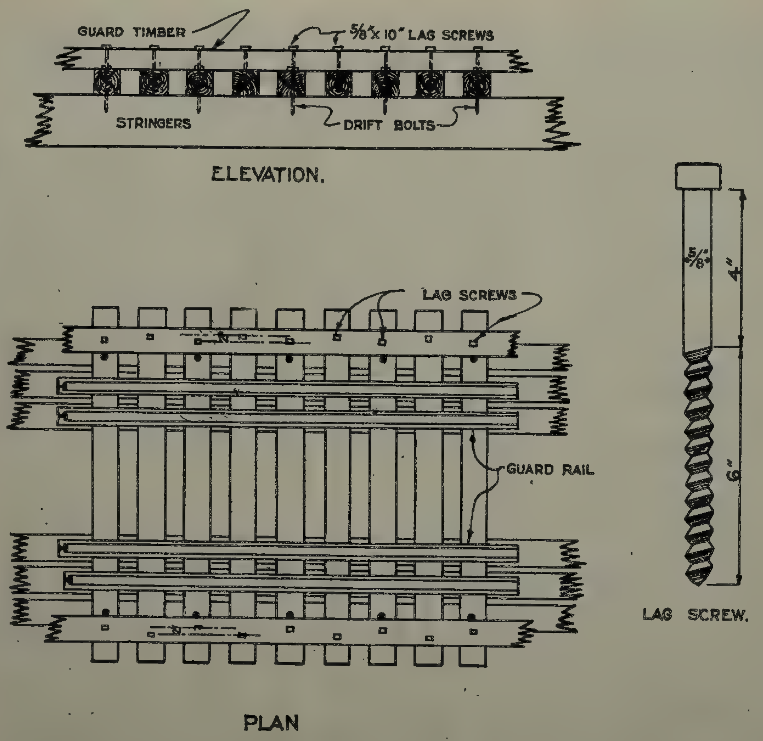
"4. On 100-ft. section the guard rails were secured with lag screws, and on adjoining 100-ft. section, the guard rails were secured by bolts ¾ in. by 16 in.

"5. Lag screws used on 100 ft. of bridge.

"6. An inspection of lag screws was made September 30, 1916, at which time 21 of a total of 200 were found to be loose, and were tightened up. On the same date an inspection of the adjoining section was made, on which the guard rails were secured by bolts, and 105 bolts were found to be loose out of a total of 200, or 52 per cent. All bolts were tightened and placed in good condition at the time of this inspection.

"On December 1, 1917, another inspection was made and all lag screws were found to be tight. On the 100-ft. section on which bolts were used, we found that 24 nuts and washers had dropped off the bolts and 47 other nuts were loose. We estimated that it will cost $3.00 for labor and material to replace the nuts and washers and to tighten the bolts that are now loose, while no expenditure is necessary at this time on the lag screws.

"7. The lag screws effectively held the ties from bunching.



NOTE !

Ties and Guard Timbers to be sized one dimension.
Omit dapping of Guard Timbers and Ties.
Use Lag Screws in every Tie.
Holes to be bored for Lag Screws one inch deeper than penetration of Lag Screw.
Holes to be bored 1/16" smaller than diameter of Lag in Guard Timber, and 1/4" smaller than diameter of Lag in Ties.
Lag Screws must not be driven but screwed to position
Fasten alternate ties to Stringers.
Lag screws to be staggered 2" in Guard Timbers.

AMERICAN RAILWAY ENGINEERING ASS'N,
RECOMMENDATIONS OF COMMITTEE VII
WOODEN BRIDGES AND TRESTLES
METHOD OF FASTENING GUARD TIMBERS
TO TIES ON DECK OF WOODEN TRESTLES.

FIG. 1.

"8. The total first cost of applying the guard rails with bolts on 100-ft. section of bridge was $42.95. The total first cost of applying the guard rails with lag screws on 100-ft. section of bridge was $16.59, showing a difference of $26.36 in first cost in favor of the lag screws. From February 9, 1916, to December 1, 1917, the period covered by the test, $3.90 was expended for tightening bolts, and only 22 cents for tightening lag screws.

"9. This test has proved that lag screws are more effective for fastening guard rails than bolts, and the above figures indicate that lag screws are much cheaper to apply and maintain, and give better results."

REPORT OF COMMITTEE IX—ON SIGNS, FENCES AND CROSSINGS.

W. F. Strouse, *Chairman;*
F. D. Batchellor,
H. E. Billman,
C. G. Bryan,
G. F. Black,
A. C. Copland,
A. S. Butterworth,
B. J. Dalton,
F. T. Darrow,
G. N. Edmondson,
R. C. Gowdy,
Arthur Crumpton, *Vice-Chairman;*
Paul Hamilton,
Maro Johnson,
L. C. Lawton,
S. L. McClanahan,
L. A. Mitchell,
T. E. Rust,
A. Swartz,
W. D. Warren,
W. D. Williams,
K. G. Williams,

Committee.

To the American Railway Engineering Association:

The Board of Direction assigned the following outline of work for the consideration of your Committee:

1. Make critical examination of the subject-matter in the Manual and submit definite recommendations for changes, taking into special consideration the subject of flangeways, both when the street or highway is or is not occupied by street or interurban railway tracks.

2. Report on subject of "Signs" and the principles of design and the rules for their use, considering the adoption of a standard sign for general use as far as possible. Study in this connection, in collaboration with Committee on Signals and Interlocking, the design of suitable day and night (if necessary) marks or signs for switch signals, derail switches, stop posts, slow posts, resume speed posts, water station and trackpan markers, highway crossing signals, etc. Also consider the location of signs, having in mind the matter of safety of employes obliged to use the roadway.

4. Report on legal requirements relative to the provision of fences for right-of-way and of stock-guards.

5. Report on classification of fences into "types."

6. Make a comprehensive study of crossings:
   (a) Grade crossings.
   Crossing gates.
   Crossing signal bells.
   Warning signals.
   (b) Over- and under-grade crossings.
   Study the laws and requirements of the Federal Government of the various States, Provinces or Municipalities which affect the distribution of cost as between the carrier and the public.

7. Make a careful investigation of all styles of manufactured posts that have been in use long enough to warrant any conclusion as to their durability, with particular attention to:

   (a) A study of various types of end or strain posts used with steel fence posts, with a view to recommending a type which would be a satisfactory substitute for posts set in concrete, the cost of which is high in those now in use.

(b) An investigation as to the best method of bracing concrete end or strain posts.

(c) A further study of the subject of concrete fence posts now in use by the various railroads.

8. Submit a revised analysis of the comparative annual cost of fences, using wood, metal and concrete posts, with a view to bringing this subject, considered by the Committee in 1912, up to date.

For the purpose of considering the above, the following Sub-Committees were appointed:

Subject No. 1—L. A. Mitchell and A. Swartz. Subject No. 2—for Eastern Railroads—Arthur Crumpton, G. F. Black, G. N. Edmondson, W. D. Warren; for Western Railroads—L. C. Lawton, S. L. McClanahan, B. J. Dalton, F. T. Darrow and R. C. Gowdy. Subject No. 5—F. D. Batchellor, Paul Hamilton and A. C. Copland. Subject No. 6—H. E. Billman, K. G. Williams and A. S. Butterworth. Subjects Nos. 7 and 8—T. E. Rust, C. G. Bryan and Maro Johnson.

COMMITTEE MEETINGS.

Your Chairman met representatives of the Sub-Committees having under consideration Subjects No. 1, 2, 6, 7 and 8, in Chicago, October 18, 1917, at which meeting there were present the following members: H. E. Billman, A. S. Butterworth, F. T. Darrow, Maro Johnson, L. A. Mitchell, T. E. Rust and K. G. Williams.

(1) FLANGEWAYS.

A report on this subject appears in Appendix A, and the recommendations of the Committee are given at the end of that section for approval and publication in the Manual.

(2) SIGNS—THE PRINCIPLES OF DESIGN AND RULES FOR THEIR USE.

The report on this subject is given in Appendix B, and is presented as information.

(4) LEGAL REQUIREMENTS RELATIVE TO RIGHT-OF-WAY FENCES AND STOCK GUARDS.

Appendix C is a report on this subject, and it is submitted as useful information.

(5) TYPES OF FENCES.

A report on this subject is given in Appendix D. The recommendations of the Committee are submitted for approval and publication in the Manual.

(6-b) OVER- AND UNDER-GRADE CROSSINGS.

In Appendix E your Committee submits a compilation of the legal requirements for over-and under-grade crossings.

(7-a) END OR STRAIN POSTS; (7-b) CONCRETE FENCE POSTS; (8) ANALYSIS OF COST.

Appendices F. G and H contain reports on these three subjects. The recommendations of the Committee for publication in the Manual are given in Appendix G.

CONCLUSIONS.

Your Committee recommends that the following action be taken on its report:

1. That the recommendations under "Flangeways," in Appendix A, be approved and published in the Manual.
2. That the recommendations of the Committee in reference to "Types of Fences," Appendix D, be approved and published in the Manual.
3. That the recommendations of the Committee in reference to "Concrete Fence Posts," Appendix G, be approved and published in the Manual.
4. That the remainder of the report be accepted as information.

Respectfully submitted,

THE COMMITTEE ON SIGNS, FENCES AND CROSSINGS.

Appendix A.

(1) FLANGEWAYS.

L. A. Mitchell, Chairman, Sub-Committee.

Last year your Committee submitted considerable information relative to depth and width of flangeways in use on steam and electric railways throughout the United States. Owing to the great variety in dimensions of flangeways and to the great amount of information submitted by the railroads, your Committee was not able to present this information in the form it desired, nor was it able to make any study looking to a recommendation for standard dimensions of flangeways. During the year this information has been tabulated showing the dimensions of flangeways in use on the different steam and electric railways, which information will be found in the following tables:

Table A—Dimensions of flangeways of electric railways crossing steam railways.
Table B—Dimensions of flangeways of electric railways crossing electric railways.
Table C—Dimensions of flangeways of steam railways crossing steam railways.
Table D—Dimensions of flangeways of steam railways crossing electric railways.
Table E—Dimensions of flangeways of steam railways where cast frogs are used.
Table F—Dimensions of flangeways of electric railways where cast frogs are used.

After a careful consideration of the above data, the Committee recommends the following dimensions for flangeways:

STRAIGHT TRACK.

Steam Railways			Electric Railways		
Depth of Flange	Width of Flangeway	Depth of Flangeway	Depth of Flange	Width of Flangeway	Depth of Flangeway
M. C. B. Standard	1¾"	1⅞"	⅞"	1⅝"	1⅛"
			1"	1⅝"	1¼"
			1⅛"	1¾"	1⅜"

For flangeways in curved tracks of steam railways an increase in width of 1/16-inch for every two degrees of curvature over two degrees is recommended. For flangeways in curved tracks of electric railways no special increase is recommended, as the above dimensions cover ordinary operating conditions. On some roads the width of flangeway is increased as the gage is increased, so as to keep the distance between the gage line and wearing surface of the opposite guard rail uniformly 4 ft. 6¾ in., which is good practice and recommended for excessive curvature.

For flangeways of steam railway tracks located in paved streets, the reports show widths generally ranging from 1½ in. to 2½ in., with one case each of 3 in. and 4 in. These flangeways are, as previously reported, formed by rails laid on side, rails placed upright with separators, planks and other paving materials, and special guard rails. For flangeways of electric railway tracks, located in paved streets, the widths generally range between 1½ in. and 2 in., although one case reported a width of 3 in., another 3½ in.

The depth of flangeways of steam railway tracks varies generally from 1¼ in. to 2 in., with two cases of 3 in.; while the depth of flangeways of electric railway tracks varies generally from ⅞-inch to 1¾ in.

TABLE A—ELECTRIC FLANGEWAYS

RAILROAD	70 lb.				75 lb.				80 lb.				85 lb.				90 lb.				100 lb.			
	Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved	
	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches
Steam																								
Baltimore & Ohio	1¾	2	Var.	2	1¾	2	Var.	2	1¾	2	Var.	2	1¾	2	Var.	2	1¾	2	Var.	2	1¾	2	Var.	2
Boston & Albany																					1¾	1⅞	Var.	1⅞
Chicago, Burlington & Quincy	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞
Chicago & Eastern Illinois	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞
Chicago Great Western													1¾	1⅞										
Chicago, Milwaukee & St. Paul					1½	1⅛							1½	1¼			1½	1¼						
Chicago, Rock Island & Pacific	1⅜	⅞			1⅜	⅞			1⅜	⅞			1⅜	⅞			1⅜	⅞			1⅜	⅞		
Clev., Cin., Chicago & St. Louis									1⅝	1⅞							1⅝	1⅞						
El Paso and Southwestern					1¾	1¾																		
Fonda., John. & Glov.									1⅝	1¼	Var.	1¼												
Great Northern																	1¼	⅞	1¼	⅞				
Gulf, Colorado & Santa Fe	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾				
Illinois Central	1⅜	⅞			1⅜	⅞			1⅜	⅞			1⅜	⅞			1⅜	⅞			1⅜	⅞		
Indiana Harbor Belt									1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞					1¾	1⅞	Var.	1⅞
Maine Central													1¼	1¼										
Missouri Pacific (St. Louis Office)	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞
Missouri Pacific (Kansas City Office)	1¾	1¾			1¾	1¾			1¾	1¾			1¾	1¾			1¾	1¾			1¾	1¾		
Nashville, Chattanooga & St. Louis									1¼	¾	1½	¾	1¼	¾	1½	¾	1¼	¾	1½	¾				
New York, Chicago & St. Louis					1⅜	1¼	1⅜	1¼					1⅜	1¼	1⅜	1¼	1⅜	1¼	1⅜	1¼				
New York Central					1⅜	1⅛			1⅜	1⅛			1⅜	1⅛			1⅜	1⅛						
Norfolk Southern	1¾	1½							1¾	1½							1¾	1½						
Northern Pacific													1¾	2	2	2	1¾	2	2	2	1¾	2	2	2
No. Pac. (West of Para Div. Mont.)	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞
Pittsburgh & Lake Erie																	1⅜	⅞						
Philadelphia & Reading	1¾	1⅞			1¾	1⅞			1¾	1⅞			1¾	1⅞			1¾	1⅞			1¾	1⅞		
Pere Marquette	1½	1			1½	1							1½	1			1½	1						
Southern Pacific	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞
Texas & Pacific					1½	1¾	Var.	1¾					1½	1¾	Var.	1¾								
Toledo, St. Louis & Western	1½	1⅞			1½	1⅞			1½	1⅞			1½	1⅞			1½	1⅞			1½	1⅞		
Virginian													1¼	1⅞										
Wheeling & Lake Erie	1	1							1	1							1	1						

TABLE B—ELECTRIC FLANGEWAYS

RAILROAD	70 lb.				75 lb.				80 lb.				85 lb.				90 lb.				100 lb.			
	Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved	
	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches
Electric																								
Bay State Railway	....	....	....	....	....	....	....	....	....	....	....	....	1¼	⅞	1¼	⅞	....	....	....	....	1¼	⅞	1¼	⅞
Berkshire Street Railway	1¼	1⅛	....	....	1¼	1⅛	....	....	1½	1½	....	....	1½	1½	....	....	1½	1½	....	....	1½	1½	....	....
Boston Elevated	....	....	....	....	....	....	....	....	....	....	....	....	1½	1½	1⅝	1½	....	....	....	....	....	....	....	....
Brooklyn Rapid Transit	....	....	....	....	....	....	....	....	1¼	¾	1 9/16	¾	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, Lake Shore & South Bend	1⅝	1¾	1⅞	1¾	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, Ottawa & Peoria	1⅞	1¾	....	....	1⅞	1¾	....	....	1⅞	1¾	....	....	1⅞	1¾	....	....	1⅞	1¾	....	....	1⅞	1¾	....	....
Chicago, North Shore & Milwaukee	....	....	....	....	....	....	....	....	1¾	1½	1⅞	1½	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, South Bend & Northern Ind.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1¾	1¾	1¾	1¾
Chicago Surface Lines	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 3/16	11/16	....	....
Cincinnati Traction Co	1¼	1⅛	1⅜	1⅛	1¼	1⅛	1⅜	1⅛	1¼	1⅛	1⅜	1⅛	1¼	1⅛	1⅜	1⅛	1¼	1⅛	1⅜	1⅛	1¼	1⅛	1⅜	1⅛
Cleveland Railway	1⅜	1⅛	Var.	1⅛	1⅜	1⅛	Var.	1⅛	1⅜	1⅛	Var.	1⅛	1⅜	1⅛	Var.	1⅛	1⅜	1⅛	Var.	1⅛	1⅜	1⅛	Var.	1⅛
Denver Tramway Co	1⅜	15/16	1⅝	15/16	1⅜	15/16	1⅝	15/16	1⅜	15/16	1⅝	15/16	1⅜	15/16	1⅝	15/16	1⅜	15/16	1⅝	15/16	1⅜	15/16	1⅝	15/16
Detroit United Ry	....	....	....	....	....	....	....	....	1⅜	13/16	1½	1⅝	....	....	....	....	....	....	....	....	....	....	....	....
East St. Louis & Suburban Ry	1½	1¾	1½	1¾	1½	1¾	1½	1¾	1½	1¾	1½	1¾	1½	1¾	1½	1¾	1½	1¾	1½	1¾	1½	1¾	1½	1¾
Indiana Traction & Terminal Co	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛
Kansas City Ry	1¾	1⅛	1¾	1⅛	1¾	1⅛	1¾	1⅛	1¾	1⅛	1¾	1⅛	1¾	1⅛	1¾	1⅛	1¾	1⅛	1¾	1⅛	1¾	1⅛	1¾	1⅛
Lake Shore Electric Railway	....	....	....	....	....	....	....	....	....	....	....	....	1⅝	1⅝	....	....	....	....	....	....	1⅝	1⅝	....	....
Los Angeles Railway	1¼	1¼	1⅜	1¼	1¼	1¼	1⅜	1¼	1¼	1¼	1⅜	1¼	1¼	1¼	1⅜	1¼	1¼	1¼	1⅜	1¼	1¼	1¼	1⅜	1¼
Mass. N. E. St. Ry	1¼	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1¼	1	....	....	....	....	....	....
Metropolitan West Side Elevated	....	....	....	....	....	....	....	....	1⅞	1¾	1⅞	2	....	....	....	....	....	....	....	....	....	....	....	....
Michigan Railway	1⅜	1⅛	1½	1⅛	1⅜	1⅛	1½	1⅛	1⅜	1⅛	1½	1⅛	1⅜	1⅛	1½	1⅛	1⅜	1⅛	1½	1⅛	1⅜	1⅛	1½	1⅛
Montreal Tramways	....	....	....	....	....	....	....	....	1½	....	1½	....	....	....	....	....	....	....	....	....	....	....	....	....
New Orleans Railway & Light Co	....	....	....	....	....	....	....	....	....	....	....	....	1	⅞	1¼	⅞	1	⅞	1¼	⅞	1	⅞	1¼	⅞
Northern Electric Railway	....	....	....	....	1¾	1¾	2	1¾	....	....	....	....	....	....	....	....	1¾	1¾	2	1¾	....	....	....	....
Omaha & Council Bluffs Street Ry	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1⅜	13/16	Var.	13/16	....	....	....	....
Pacific Electric Railway	1¾	1¼	1¾	1¼	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾
Southern Illinois Railway & Power Co.	2½	2½	2¾	2½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Terminal R. R. Assn. of St. Louis	....	....	....	....	....	....	....	....	1¾	1¾	1¾	1¾	....	....	....	....	....	....	....	....	1¾	1¾	1¾	1¾
Terre Haute, Indiana & East	1⅜	1	1⅜	1	1⅜	1	1⅜	1	1⅜	1	1⅜	1	1⅜	1	1⅜	1	1⅜	1	1⅜	1	1⅜	1	1⅜	1
Twin City Rapid Transit	....	....	....	....	....	....	....	....	....	....	....	....	1⅜	⅞	1½	⅞	1⅜	⅞	1½	⅞	....	....	....	....
Union Traction Company of Indiana	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛	1⅝	1⅛	1¾	1⅛
United R. R. of San Francisco	....	....	....	....	....	....	....	....	1¼	1¼	....	....	....	....	....	....	....	....	....	....	1¼	1¼	....	....
United Railway Co. of St. Louis	....	....	....	....	....	....	....	....	1⅛	¾	....	....	1⅛	¾	....	....	....	....	....	....	1⅛	¾	....	....
Washington, Baltimore & Amer. Elec	....	....	....	....	....	....	....	....	1⅝	1¾	1⅝	1¾	....	....	....	....	....	....	....	....	....	....	....	....
Washington Railway & Electric Co	....	....	....	....	....	....	....	....	....	....	....	....	1½	1¾	....	....	....	....	....	....	....	....	....	....
Waterloo, Cedar Falls & Northern	....	....	....	....	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	....	....	....	....
Wilmington & Philadelphia Trac. Co.	1¼	1	1 9/16	1	1¼	1	1 9/16	1	1¼	1	1 9/16	1	1¼	1	1 9/16	1	1¼	1	1 9/16	1	1¼	1	1 9/16	1

TABLE C—STEAM FLANGEWAYS

RAILROAD	70 lb.				75 lb.				80 lb.				85 lb.				90 lb.				100 lb.			
	Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved	
	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches
Steam																								
Atchison, Topeka & Santa Fe	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾				
Baltimore & Ohio	1¾	2	Var.	1¾	1¾	2	Var.	2	1¾	2	Var.	2	1¾	2	Var.	2	1¾	2	Var.	2	1¾	2	Var.	2
Bangor & Aroostook	1¾	1⅝	2½	1⅝									1¾	1⅝	2½	1⅝								
Boston & Albany																					1¾	1⅞	Var.	1⅞
Buenos Aires Western													1¾	2¼										
Canadian Government									1¾	1⅞	1¾ 2⅛	1⅞	1¾	1⅞	1¾ 2⅛	1⅞								
Canadian Pacific									1¾	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞								
Central R. R. of New Jersey	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞
Chicago, Burlington & Quincy	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞
Chicago & Eastern Illinois	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞
Chicago Great Western (East. Div.)													1¾	1⅞	2⅛	1⅞					1¾	1⅞		
Chicago Great Western (West. Div.)					1¾	1⅞	Var.	1⅞					1¾	1⅞	Var.	1⅞					1¾	1⅞	Var.	1⅞
Chicago Junction									1¾	2	2	2												
Chicago, Milwaukee & St. Paul					1¾	1¾							1¾	1⅞			1¾	1⅞			1¾	1⅞		
Chicago, Rock Island & Pacific	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞
Clev., Cin., Chi. & St. L. (Mat. off)	1¾	1¾			1¾	1¾			1¾	1¾			1¾	1¾			1¾	1¾			1¾	1¾		
Clev., Cin., Chi. & St. L. (Gal. off)									1¾	1⅞							1¾	1⅞						
Del., Lack. & Western	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞
Duluth & Iron Range									1¾	2							1¾	2						
El Paso & Southwest					1¾	1¾																		
Fonda, John. & Glov.									1¾	1¾	1¾	1¾												
Grand Trunk	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞
Great Northern																	1⅞	1⅞	Var.	1⅞				
Gulf, Colorado & Santa Fe	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾	1¾	1¾	Var.	1¾				
Illinois Central	1¾		Var.		1¾		Var.		1¾		Var.		1¾		Var.		1¾		Var.		1¾		Var.	
Indiana Harbor Belt									1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞					1¾	1⅞	Var.	1⅞
Indianapolis & Frank	1¾	2			1¾	2			1¾	2			1¾	2			1¾	2			1¾	2		
International & Great Northern					1¾	1⅞	2	1⅞	1¾	1⅞	2	1⅞												
Kansas City Terminal					1¾	1⅞	2⅛	1⅞									1¾	1⅞	2⅛	1⅞				
Lake Erie & Western	1¾	Var.	Var.	Var.	For all weights.																			

Long Island R. R.	1¾	2⅛	Var.	2⅛	1¾	2⅛	Var.	2⅛	1¾	2⅛	Var.	2⅛	1¾	2⅛	Var.	2⅛	1¾	2⅛	Var.	2⅛	1¾	2⅛	Var.	2⅛
Los Angeles & Salt Lake	.....	.....	.....	.....	1⅞	1⅞	.....	.....	.....	.....	.....	.....	1⅞	1⅞	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Louisiana & Arkansas	.....	.....	.....	.....	1⅝	1¾	1⅞	1¾	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Maine Central	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1¾	1¾	Var.	1¾	.....	.....	.....	.....	.....	.....	.....	.....
Minn., St. Paul & Sault Ste. Marie	.....	.....	.....	.....	.....	.....	.....	.....	1⅞	1¾	Var.	1¾	1⅞	1¾	Var.	1¾	.....	.....	.....	.....	.....	.....	.....	.....
Missouri, Kansas & Texas	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	.....	.....	.....	.....
Missouri Pacific (St. Louis Office)	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞
Missouri Pacific (Kansas City Office)	1¾	1¾	.....	.....	1¾	1¾	.....	.....	1¾	1¾	.....	.....	1¾	1¾	.....	.....	1¾	1¾	.....	.....	1¾	1¾	.....	.....
Nashville, Chattanooga & St. Louis	.....	.....	.....	.....	.....	.....	.....	.....	1¾	1⅞	2	1⅞	1¾	1⅞	2	1⅞	1¾	1⅞	2	1⅞	.....	.....	.....	.....
New York, Chicago & St. Louis	.....	.....	.....	.....	1¾	2	1¾	2	1¾	2	1¾	2	1¾	2	1¾	2	1¾	2	1¾	2	1¾	2	1¾	2
New York Central (Grand Central)	1¾	1⅞	.....	.....	1¾	1⅞	.....	.....	1¾	1⅞	.....	.....	1¾	1⅞	.....	.....	1¾	1⅞	.....	.....	1¾	1⅞	.....	.....
New York Central (Buffalo Eastern)	.....	.....	.....	.....	.....	.....	.....	.....	1¾	1⅞	Var.	1⅞	.....	.....	.....	.....	.....	.....	.....	.....	1¾	1⅞	Var.	1⅞
New York Central (T. & O. C.)	1¾	1¾	Var.	1¾	.....	.....	.....	.....	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	1¾	1⅞	Var.	1⅞	.....	.....	.....	.....
New York Central (Buffalo Western)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1¾	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
New Zealand Government	1⅝	1⅝	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Norfolk Southern	1¾	1½	.....	.....	.....	.....	.....	.....	1¾	1½	.....	.....	.....	.....	.....	.....	1¾	1½	.....	.....	.....	.....	.....	.....
Northern Pacific	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1¾	1⅞	2	1⅞	1¾	1⅞	2	1⅞	1¾	1⅞	2	1⅞
Northern Pacific (West of Paradise)	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞
Penna. Lines (West of Pittsburgh)	1¾	2	Var.	2	.....	.....	.....	.....	.....	.....	.....	.....	1¾	2	Var.	2	.....	.....	.....	.....	1¾	2	Var.	2
Penna. Lines (Indiana. Office)	2	1 5/16	2	1 5/16	.....	.....	.....	.....	.....	.....	.....	.....	2	1 5/16	2	1 5/16	.....	.....	.....	.....	2	1 7/16	2	1 7/16
Pittsburgh & Lake Erie	1¾	Var.	Var.	Var.	For all weights.																			
Pere Marquette	1¾	1⅞	.....	.....	1¾	1⅞	.....	.....	.....	.....	.....	.....	1¾	1⅞	.....	.....	1¾	1⅞	.....	.....	.....	.....	.....	.....
Salt Lake Route	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞
Seaboard Air Line	1⅞	2	1⅞	2	1⅞	2	1⅞	2	1⅞	2	1⅞	2	1⅞	2	1⅞	2	1⅞	2	1⅞	2	1⅞	2	1⅞	2
Southern Pacific	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞
Southern Railway	1⅞	2	2⅛	2	1⅞	2	2⅛	2	1⅞	2	2⅛	2	1⅞	2	2⅛	2	.....	.....	.....	.....	.....	.....	.....	.....
St. Joseph & Grand Island	.....	.....	.....	.....	1⅞	1⅞	Var.	1⅞	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Texas & Pacific	.....	.....	.....	.....	1¾	1¾	Var.	1¾	.....	.....	.....	.....	1¾	1¾	Var.	1¾	.....	.....	.....	.....	.....	.....	.....	.....
Toledo, St. Louis & Western	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞
Virginian	1⅞	1⅞	.....	.....	1⅞	1⅞	.....	.....	.....	.....	.....	.....	1⅞	1⅞	.....	.....	.....	.....	.....	.....	1⅞	1⅞	.....	.....
Wabash Railway	1¾	1⅞	1¾	1⅞	.....	.....	.....	.....	1¾	1⅞	1¾	1⅞	.....	.....	.....	.....	1¾	1⅞	1¾	1⅞	.....	.....	.....	.....
Wabash R. R.	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	.....	.....	.....	.....
Washington Terminal Co	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1¾	1¾	.....	.....	.....	.....	.....	.....	1¾	1¾	.....	.....
Wheeling & Lake Erie	1¾	1¾	.....	.....	.....	.....	.....	.....	1¾	2	.....	.....	.....	.....	.....	.....	1¾	2	.....	.....	.....	.....	.....	.....

TABLE D—STEAM FLANGEWAYS

RAILROAD	70 lb.				75 lb.				80 lb.				85 lb.				90 lb.				100 lb.			
	Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved		Straight		Curved	
	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches	Width, Inches	Depth, Inches
Electric																								
Bay State Street Railway	....	....	....	....	....	....	....	....	....	....	....	....	2	....	2	1⅞	....	....	....	....	2	....	2	1⅞
Berkshire Street Railway	2	2	....	....	2	2	....	....	2	2	....	....	2	2	....	....	2	2	....	....	2	2	....	....
Boston Elevated Railway	....	....	....	....	....	....	....	....	....	....	....	....	2	2	2	2	....	....	....	....	....	....	....	....
Brooklyn Rapid Transit	....	....	....	....	....	....	....	....	1⅞	2	1⅞	2	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, Lake Shore & South Bend	1⅝	1¾	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, North Shore & Milwaukee	....	....	....	....	....	....	....	....	1¾	1½	1⅞	1½	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, South Bend & Northern Ind.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1¾	1¾	1¾	1¾
Chicago Surface Lines	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1¾	1¾	2	1¾
Cleveland Railway	1¾	1¾	Var.	1¾	1¾	$1\frac{13}{16}$	Var.	$1\frac{13}{16}$	1¾	1⅞	Var.	1⅞	1¾	$1\frac{15}{16}$	Var.	$1\frac{15}{16}$	1¾	2	Var.	2	1¾	$2\frac{3}{16}$	Var.	$2\frac{1}{16}$
Denver Tramways Co.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1⅞	1½	....	....
Detroit United	....	....	....	....	....	....	....	....	1¾	$1\frac{15}{16}$	1¾	$1\frac{15}{16}$	....	....	....	....	....	....	....	....	....	....	....	....
East St. Louis & Suburban	1¾	1¾	....	....	1¾	1¾	....	....	1¾	1¾	....	....	1¾	1¾	....	....	1¾	1¾	....	....	1¾	1¾	....	....
Indiana Traction & Terminal Co.	1¾	1½	2	1½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Kansas City Railway	1¾	1¼	Var.	1¼	1¾	1¼	Var.	1¼	1¾	1¼	Var.	1¼	1¾	1¼	Var.	1¼	1¾	1¼	Var.	1¼	1¾	1¼	Var.	1¼
Lake Shore Electric Railway	....	....	....	....	....	....	....	....	....	....	....	....	1¾	1¾	....	....	....	....	....	....	1¾	1¾	....	....
Mass. N. E. Street Railway	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	2	....	....	....	....	....	....
Metropolitan West Side Elevated	....	....	....	....	....	....	....	....	1⅞	1¾	1⅞	2	....	....	....	....	....	....	....	....	....	....	....	....
Michigan Railway Company	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾	1¾
Montreal Tramways	....	....	....	....	1¾	....	1¾	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
New Orleans Railway & Light Co.	....	....	....	....	....	....	....	....	....	....	....	....	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞
Northern Electric Railway	....	....	....	....	1¾	1¾	2	1¾	....	....	....	....	....	....	....	....	1¾	1¾	2	1¾	....	....	....	....
Omaha & Council Bluffs	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1¾	1¾	2 to 2¼	1¾	....	....	....	....
Pacific Electric	....	....	....	....	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞	1⅞	1⅞	Var.	1⅞
Southern Illinois Ry. & Power Co.	2	2½	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Terre Haute, Indiana & Eastern	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞
Twin City Rapid Transit	....	....	....	....	....	....	....	....	....	....	....	....	Var.	1¼	....	....	Var.	1¼	....	....	....	....	....	....
Union Traction Company of Indiana	1¾	1¾	1⅞	1¾	1¾	1¾	1⅞	1¾	1¾	1¾	1⅞	1¾	1¾	1¾	1⅞	1¾	1¾	1¾	1⅞	1¾	1¾	1¾	1⅞	1¾
United R. R. of San Francisco	....	....	....	....	....	....	....	....	1¾	1¾	....	....	....	....	....	....	....	....	....	....	1¾	1¾	....	....
United Railway of St. Louis	....	....	....	....	....	....	....	....	1¾	1¾	....	....	1¾	1¾	....	....	....	....	....	....	1¾	1¾	....	....
Washington, Baltimore & Ann. Elec.	....	....	....	....	....	....	....	....	1⅞	1⅞	1⅞	1⅞	....	....	....	....	....	....	....	....	....	....	....	....
Washington Railway & Electric Co.	....	....	....	....	....	....	....	....	....	....	....	....	1¾	2	....	....	....	....	....	....	....	....	....	....
Waterloo, Cedar Falls & Northern	....	....	....	....	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	1¾	1⅞	....	....	....	....
Wilmington & Philadelphia Trac. Co.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

TABLE E—CAST FROGS.

RAILROAD	70 lb.				75 lb.				80 lb.				85 lb.				90 lb.				100 lb.			
	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting
	Straight	Curved			Straight	Curved			Straight	Curved			Straight	Curved			Straight	Curved			Straight	Curved		
	Inches				Inches				Inches				Inches				Inches				Inches			
Steam																								
Baltimore & Ohio	1¾	Var.	2		1¾	Var.	2		1¾	Var.	2		1¾	Var.	2		1¾	Var.	2		1¾	Var.	2	
Boston & Albany																					1¾	Var.	1⅞	
Buenos Aires Western													1¾		2	2⅛								
Canadian Pacific													1$\frac{13}{16}$	1⅞							1$\frac{13}{16}$	1⅞		
Central R. R. of New Jersey	1¾	Var.	1⅞		1¾	Var.	1⅞		1¾	Var.	1⅞		1¾	Var.	1⅞		1¾	Var.	1⅞		1¾	Var.	1⅞	
Chicago Great Western					1¾	Var.	1⅞						1¾	Var.	1⅞						1¾	Var.	1⅞	
Chicago Junction									1¾	1¾	1⅞													
Clev., Cin., Chicago & St. Louis	1¾		1¾	1¾	1¾		1¾	1¾	1¾		1¾	1¾	1¾		1¾	1¾	1¾		1¾	1¾	1¾		1¾	1¾
Del., Lack. & West	1¾	Var.	1⅞	1⅞	1¾	Var.	1⅞	1⅞	1¾	Var.	1⅞	1⅞	1¾	Var.	1⅞	1⅞	1¾	Var.	1⅞	1⅞	1¾		1⅞	1⅞
Duluth & Iron Range									1¾		2						1¾		2					
El Paso & Southwestern					2		1¾										2¼		1¾					
Fonda, Johnstown & Gloversville									1¾	1¾	1¾	1¾												
Indianapolis & Frankfort	1¾		2		1¾		2		1¾		2		1¾		2		1¾		2		1¾		2	
Int. & Great Northern					1¾		1¼		1¾		1¼													
Kansas City Terminal Ry																	1¾		1⅞	1⅞				
Lake Erie & Western	1¾	Var.	Var.		1¾	Var.	Var.		1¾	Var.	Var.		1¾	Var.	Var.		1¾	Var.	Var.		1¾	Var.	Var.	
Long Island R. R.	1¾	Var.			1¾	Var.			1¾	Var.			1¾	Var.			1¾	Var.			1¾	Var.		
Los Angeles & Salt Lake													1⅞		1⅞		1⅞		1⅞					
Maine Central													1¾	Var.	1¾									
Minn., St. Paul & Sault Ste. Marie													1¾		1⅞		1¾		1⅞					
Missouri, Kansas & Texas													1¾	1¾	1⅞									
Missouri Pacific Railway	1¾		1¾		1¾		1¾		1¾		1¾		1¾		1¾		1¾		1¾		1¾		1¾	
New York Central											1⅞												1⅞	
New Zealand Government Railway	1⅝		1⅝																					
Norfolk Southern	1¾		1½	1½					1¾		1½	1½					1¾		1½	1½				
Pennsylvania Lines	1¾		2										1¾		2						1¾		2	
Philadelphia & Reading	1¾		1⅞		1¾		1⅞		1¾		1⅞		1¾		1⅞		1¾		1⅞		1¾		1⅞	
Salt Lake Route	1⅞		1⅞		1⅞		1⅞		1⅞		1⅞		1⅞		1⅞		1⅞		1⅞		1⅞		1⅞	
Seaboard Air Line	1¾		1⅞		1¾		1⅞		1¾		1⅞		1¾		1⅞		1¾		1⅞		1¾		1⅞	
Southern Pacific	1⅞	Var.	1⅞		1⅞	Var.	1⅞		1⅞	Var.	1⅞		1⅞	Var.	1⅞		1⅞	Var.	1⅞		1⅞	Var.	1⅞	
Southern Railway	1⅞	2⅛	2	2	1⅞	2⅛	2	2	1⅞	2⅛	2	2	1⅞	2⅛	2	2								
Washington Terminal Company													2¼	2¼	2⅛	2⅛					2¼	2¼	2⅛	2⅛

TABLE F—CAST FROGS.

RAILROAD	70 lb.				75 lb.				80 lb.				85 lb.				90 lb.				100 lb.			
	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting	Width		Depth at Pt.	Depth at end H. C. Casting
	Straight	Curved			Straight	Curved			Straight	Curved			Straight	Curved			Straight	Curved			Straight	Curved		
	Inches				Inches				Inches				Inches				Inches				Inches			
Electric																								
Bay State Street Railway	....	....	....	....	1 9/16	1 9/16	¾	1¼	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Boston Elevated	....	....	....	....	....	....	....	....	....	....	....	....	1⅝	1¾	¾	1½	....	....	....	....	....	....	....	....
Brooklyn Rapid Transit	1¼	1 9/16	11/32	1⅛	....	....	....	....	1¼	1 9/16	11/32	1⅛	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, Lake Shore & South Bend	1⅝	....	1⅞	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chicago, North Shore & Milwaukee	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 9/16	....	13/16	1⅛	....	....	....	....
Chicago, South Bend & Northern	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 9/16	1¾	⅞	1⅜
Chicago Surface Lines	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 3/16	....	11/16	....
Cincinnati Traction Company	1¼	1⅜	⅝	Var.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Cleveland Railway Co	1⅜	Var.	⅝	1	1⅜	Var.	⅝	1	1⅜	Var.	⅝	1	1⅜	Var.	⅝	1	1⅜	Var.	⅝	1	1⅜	Var.	⅝	1
Denver Tramway	1⅜	1⅝	⅝	⅞	1⅜	1⅝	⅝	⅞	1⅜	1⅝	⅝	⅞	1⅜	1⅝	⅝	⅞	1⅜	1⅝	⅝	⅞	1⅜	1⅝	⅝	⅞
East St. Louis & Suburban	1½	1½+	⅞	1¾	1½	1½+	⅞	1¾	1½	1½+	⅞	1¾	1½	1½+	⅞	1¾	1½	1½+	⅞	1¾	1½	1½+	⅞	1¾
Indiana Traction & Terminal Co	1⅝	1⅝	¾	1¼	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Kansas City Railway	1⅝	Var.	Var.	1⅛	1⅝	Var.	Var.	1⅛	1⅝	Var.	Var.	1⅛	1⅝	Var.	Var.	1⅛	1⅝	Var.	Var.	1⅛	1⅝	Var.	Var.	1⅛
Lake Shore Electric	....	....	....	....	....	....	....	....	....	....	....	....	1½	....	1	....	....	....	....	....	1½	....	1	....
Los Angeles Railway	1⅜	Var.	25/32	1⅛	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Massachusetts Northeastern	1¼	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	1¼	....	1	....	....	....	....	....
Michigan Railway Company	1⅜	1 9/16	1	....	1⅜	1 9/16	1	....	1⅜	1 9/16	1	....	1⅜	1 9/16	1	....	1⅜	1 9/16	1	....	1⅜	1 9/16	1	....
Montreal Tramway	....	....	....	....	....	....	....	....	1½	1½	Var.	1½	....	....	....	....	....	....	....	....	....	....	....	....
Northern Electric	....	....	....	....	1¾	3	1¾	1¾	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Omaha & Council Bluffs	1⅜	1 9/16	9/16	☞	For all special work.																			
Pacific Electric	1¾	1¾	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Southern Illinois Railway & Power Co.	2	2½	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Terre Haute, Indiana. & Eastern	1⅜	1⅜	13/16	1	1⅜	1⅜	13/16	1	1⅜	1⅜	13/16	1	1⅜	1⅜	13/16	1	1⅜	1⅜	13/16	1	1⅜	1⅜	13/16	1
Wilmington & Philadelphia Traction	1¼	1 9/16	⅝	1⅛	1¼	1 9/16	⅝	1⅛	1¼	1 9/16	⅝	1⅛	1¼	1 9/16	⅝	1⅛	1¼	1 9/16	⅝	1⅛	1¼	1 9/16	⅝	1⅛

Appendix B.

(2) SIGNS—THE PRINCIPLES OF DESIGN AND RULES FOR THEIR USE.

Arthur Crumpton and L. C. Lawton, Chairmen, Sub-Committees.

Your Committee had prepared a progress report embodying a set of signs for general use, the scheme being a rather radical departure from the signs at present in use on the railroads of the United States and Canada, in that lettering was largely eliminated. The underlying principle in the design was that signs used in connection with the operation of trains and for warning the public at highway crossings should be made as prominent as possible, while those delineating property and marking corporation limits, mileage, bridges, etc., should be made less conspicuous.

Upon taking the matter up with Committee X—On Signals and Interlocking, it was found that that Committee had given the matter very careful consideration, and had arrived at the following conclusion:

"Some of the so-called signs govern train operation just as much as the movable semaphore of an interlocking or block signal system, and these signs are recognized in the standard code of the American Railway Association as signals. A note to the definition of fixed signal, page 235, Rule Book of the American Railway Association, reads as follows: 'The definition of a *"Fixed Signal"* covers such signals as slow boards, stop boards, yard limits, switch, train order, block, interlocking, semaphore, disc, ball or other means for displaying indications that govern the movement of a train.' Under this definition, slow boards, stop boards, etc., are in fact signals. It seems that the work of this Committee should be confined to designing these signals, and that the designing of information signals is properly a subject to be handled by Committee No. 9, excepting that there should be conference between the two Committees to the end of avoiding any confliction which might result in confusion."

Your Committee is in accord with the above conclusion and can see no advantage in submitting another set of designs at this time.

While considering the subject of standard signs, it is felt it should first be definitely determined what signs are considered absolutely necessary for all roads, and these signs should then be divided into classes, and the classes then considered in deciding the types to be adopted. Signs naturally divide themselves into two classes—those that apply to the public, and those that apply to employes. There is no question that signs applying to the public should be conspicuous, and have such lettering on them as to make them intelligent to the public. Signs applying to employes are, to some extent, further divided for use of departments, though the more important ones are for the operation of trains. These signs should be more conspicuous than those termed information signs.

In view of the fact that we now have Government control of railroads, which may lead to the transfer of men from one road to another, as is being done with equipment, it would seem most desirable that uniform signs should be adopted by all railroads. As efforts are being made from year to year to secure more permanent materials for various structures, it is considered most desirable that concrete be utilized for all information signs and, when possible, for other signs, all suitably marked to convey the necessary information.

Appendix C.

(4) LEGAL REQUIREMENTS RELATIVE TO RIGHT-OF-WAY FENCES AND STOCK-GUARDS.

Prepared by W. F. Strouse.

Last year your Committee submitted abstracts from the laws of the various states of the Union and Canada, on the legal requirements relative to provision of fences for right-of-way and installation of stock-guards. In the discussion of the report at that time, it was suggested that a tabulated statement be prepared, giving the principal information shown in the abstracts—when the laws were passed, what constituted a legal fence, and other information of this character. Your Committee now wishes to present, in tabulated form, the information suggested in the discussion.

The above-mentioned laws were secured, as a rule, through the legal departments of the railroad companies throughout the country, and, in most cases, gave the reference and date when the laws were passed. Where this information is not shown, a notation has been made that the laws referred to are those in force in 1916.

It will be noted that the laws of but nineteen states and the Dominion of Canada specify the height of a legal fence, and that the laws of but twenty-six states and the Dominion of Canada specify the material to be used in their construction. The laws of a number of the remaining states are entirely silent on the matter of what constitutes a legal fence, some of the laws making no mention whatever of the material to be used or the height, but specifying in a general way that the right-of-way shall be fenced so as to turn the various kinds of live stock. In a few instances, the railroad companies are obliged to secure the approval of the railroad commission for both fences and stock-guards.

From the above, it would seem apparent that some concerted action should be taken by this Association, or by some other similar body, looking to the adoption of a uniform fence law. Under present conditions, it is difficult in many cases to decide damage cases on account of the uncertainty as to what constitutes a legal fence.

LEGAL REQUIREMENTS FOR FENCES AND STOCK-GUARDS

States	Fences Required by Statute		Stock-Guards Required by Statute		Legal Fences		Date and Reference
	Against cattle, horses and mules	Against sheep and swine	Against cattle, horses and mules	Against sheep and swine	Mat.	Ht.	
Alabama........	Approval of Yes	R. R. Com Yes	mission req Yes	uired. Yes			Code of 1907.
Arizona........	Yes	Yes	Yes	No			Session laws 1905.
Arkansas.......	Certain Counties	Certain Counties	Yes	Yes	Wood Wire		Acts of 1913.
California......	Yes	Yes	No	No			Civil Code 1909.
Canada.........	Yes	Yes	Yes	Yes	Wire, Wood	4′ 6″	Railway Act 1904.
Colorado.......	Yes	Yes	Yes	Yes			Laws of 1911.
Connecticut....	Must have Yes	approval of No	Railroad Co Yes	mmission. No			Old Laws of 1836.
Delaware.......	Yes	Yes	Yes	Yes			Revised Code 1915.
Florida.........	Yes	Yes	Yes	Yes	Wood, Wire		In force in 1916.
Georgia.........	Yes	Yes	Yes	Yes	Wood, Wire	4′ 0″	In force in 1916.
Idaho..........	Yes	Yes	Yes	Yes		4′ 0″	Session Laws 1911.
Illinois.........	Yes	Yes	Yes	Yes			In force in 1916.
Indiana.........	Yes	Yes	Yes	Yes	Wood, Wire		Burn's Annotated Statute 1914.
Indian Territory	No	Laws.	No.	Laws.			
Iowa...........	Yes	Yes	Yes	Yes	Wire, Wood	4′ 6″	Code of 1897.
Kansas.........	Railroads a not fence	re liable if d.	Yes	Yes	Wire, Wood	4′ 6″	General Statute 1909.
Kentucky......	Yes	Yes	Yes	Yes			1900.
Louisiana.......	Not liable i No	f fences and No	stock-guards No	are provide No	d.		Act 110, 1886.
Maine..........	Yes	Yes	Requires ap Railroad C Yes	proval of ommission. No			Revised Statute.
Maryland......	Cecil No	County. No	No	No	Wood, Woven Wire	4′ 0″	Code of 1904.
Massachusetts..	Approval of Yes	Railroad Co Yes	mmission re Yes	quired.	Wood, Mas. Emb.		Revised Laws 1906.
Michigan.......	Approval of Yes	Railroad C Yes	ommission r Yes	equired.	Wood, Wire	4′ 6″	
Minnesota......	Yes	Yes	Yes		Woven Wire		General Statute 1913.
Mississippi......	Yes	Yes	No				Code of 1906.
Missouri........	Yes	Yes	Yes		Wood, Wire	4′ 6″	In force in 1916.
Montana........	Yes	Yes	Yes				Revised Code 1907.
Nebraska......	Yes	Yes	Yes				In force in 1916.
Nevada........	Yes	Yes	Yes				In force in 1916.

LEGAL REQUIREMENTS FOR FENCES AND STOCK-GUARDS

States	Fences Required by Statute		Stock-Guards Required by Statute		Legal Fences		Date and Reference
	Against cattle, horses and mules	Against sheep and swine	Against cattle, horses and mules	Against sheep and swine	Mat.	Ht.	
New Hampshire	Yes	Yes	Yes				1889.
New Jersey.....	Yes	Yes	Yes		Wood, Stone		Railroad Laws 1903.
New Mexico....	Yes	Yes	Yes	Yes	Wire, Wood	4′ 0″	Statutes of 1915.
New York	Yes	Yes	Yes	Yes	Wood, Wire	4′ 0″	In force in 1916.
North Carolina.	Yes	Yes	Yes	Yes	Does not Specify.	4′ 6″ 5′ 0″	In force in 1916.
North Dakota..	Approval of Railroad Commission required. Yes	Yes	Yes	Yes	Wire, Wood	4′ 6″	Civil Code, 1913. Amended 1915.
Ohio...........	Yes	Yes	Yes	Yes	Wire, Wood		In force in 1916.
Oklahoma......	Yes	Yes	No	No		4′ 6″	In force in 1916.
Oregon.........	Yes	Yes			Woven or Barb Wire	4′ 0″	Lord's Oregon Laws, 1913.
Pennsylvania...	County Laws. No	No	County Laws. No	No	Wood, Wire		Public Laws 1869.
Rhode Island...	Yes	Yes	No	No	Hedge Wall, Wire, Wood	4′ 6″ 4′ 0″	Public Laws 1916.
South Carolina.	Yes	Yes	Yes	Yes	Wire, Wood	4′ 6″ & 5′ 0″	In force in 1916.
South Dakota..	Yes	Yes	Yes	Yes	Wood, Wire	4′ 6″	Civil Code 1913. Amended 1915.
Tennessee......	Not liable if fences and stock-guards are provided. No	No	No	No	Stone, Wood, Wire	3′ 6″ & 4′ 6″	Shannon's Code 1889.
Texas..........	No	No	Yes	Yes			In force in 1916.
Utah...........	No Laws.		No Laws.				
Vermont.......	Yes	Yes	Yes	Yes			Public Statute 4450-4458.
Virginia........	Yes	Yes	Yes	Yes	Wood, Wire		Code of 1904.
Washington.....	Yes	Yes	Yes	Yes			R. & B. Code.
West Virginia...	Yes	Yes	Yes	Yes	Wood, Wire, Hedge	4′ 6″	1882.
Wisconsin.......	Yes	Yes	Yes	Yes		4′ 0″	1913.
Wyoming.......	Yes	Yes	Yes	Yes	Wire, Wood		Compiled Statute 1910.

Appendix D.

(5) TYPES OF FENCES.

F. D. Batchellor, Chairman, Sub-Committee.

Your Committee desires to call attention to the exhaustive report on the subject of right-of-way and snow fences made three years ago, at which time the specifications for right-of-way fences were revised for inclusion in the Manual.

This year your Committee has collected a number of photographs illustrating special fences suitable for use around industrial plants, railroad yards, etc. The investigation this year has disclosed the fact that there is a great variety of fences in use at this time for the above purpose, ranging from the ordinary wood picket fence, in general use years ago, to the solid board fence surmounted by strands of barbed wire, and from the ordinary iron picket fence to the heavy galvanized woven wire fence, surmounted by strands of barbed wire, shown in the accompanying illustrations. These fences are usually about eight feet in height, and their use has increased very rapidly within the last year or two, particularly around industrial plants engaged in the manufacture of material used in connection with the prosecution of the war.

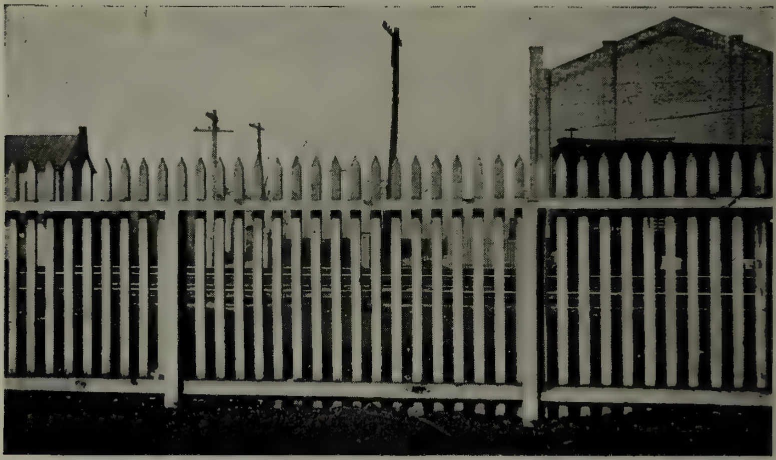


Fig. 1.

Another rather common form of fence around railroad property consists of angle iron rails and pickets with flat iron bars for posts and braces. Your Committee recommends the inclusion, in the Manual, of photographs, Figs. 1 to 9, illustrating this class of fence.

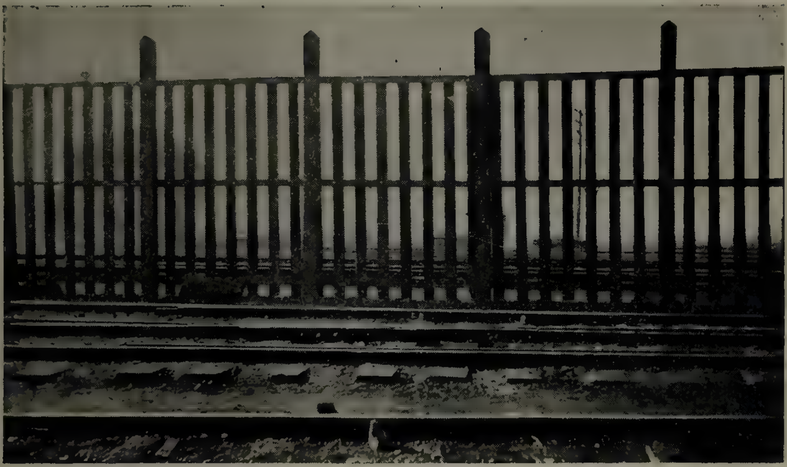


FIG. 2.

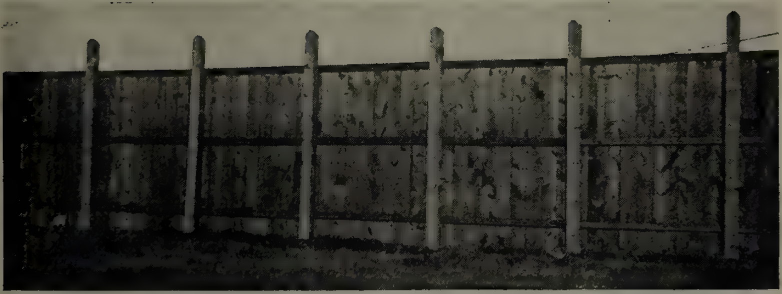


FIG. 3.

FIG. 4.

FIG. 5.

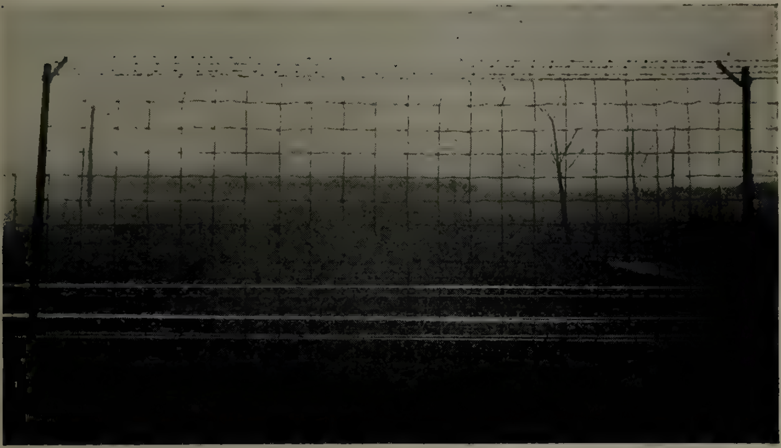


FIG. 6.

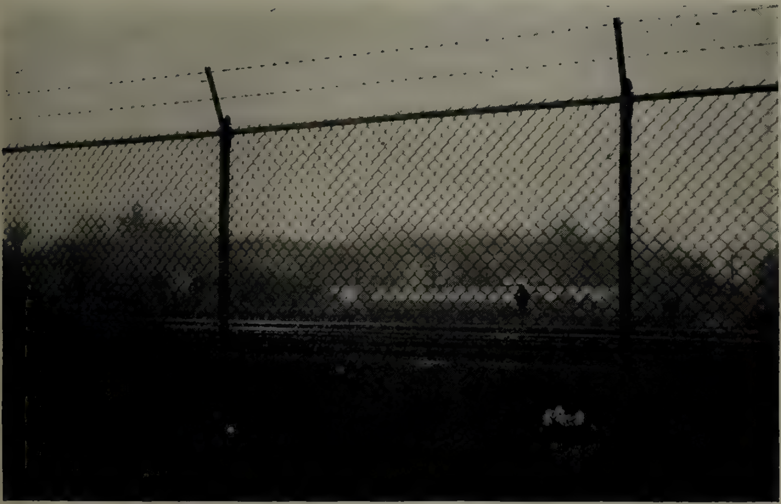


FIG. 7.

Fig. 8.

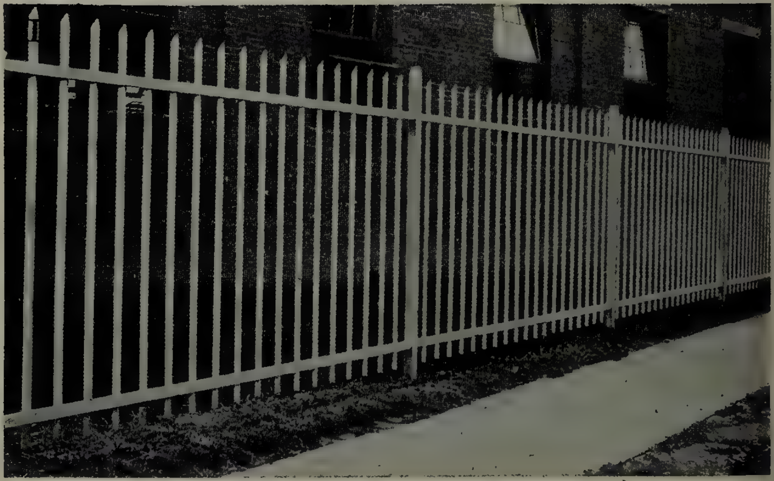


Fig. 9.

Appendix E.

(6-b) OVER- AND UNDER-GRADE CROSSINGS.

H. E. Billman, Chairman, Sub-Committee.

Under 6. (b) your Committee has secured the following information for the various states:

Alabama.

PUBLIC SERVICE COMMISSION.

In the absence of a reply from the Public Service Commission, following is quoted from the City Engineer of Birmingham:

"We have a State law which undertakes to force the railroad companies to pay the entire expense, including the consequential damages. However, this law has never been tried out in the courts.

"In the case of the only two viaducts which have been built since this law was enacted, the City and the railroads have gotten together as to the proportioning of the cost. In one instance the City paid 30 per cent. and in another instance 20 per cent. of the entire cost, including consequential damages."

From data collected it appears that in the past the expense has been divided by agreement between the parties interested. It seems to depend to some extent upon who initiates the request for the separate grades as well as priority of one corporation over another at any point. There are instances where the Municipality has borne the entire cost of viaducts. In other cases the railroads have borne the entire expense, and in still others the Street Railway has borne the entire cost.

However, in most instances the expense is distributed between the City, the Railroads, the Street Railway, Public Service Corporations and others. No information is at hand indicating that the State shares in the cost of grade crossing elimination. One reply indicates that the County does not share in the cost of work done within the corporate limits of a municipality.

Arizona.

CORPORATION COMMISSION OF ARIZONA.

No grade crossing of a railroad and highway can be established without the permission of the Corporation Commission, which may refuse such permission or grant it upon such terms and conditions as it may prescribe.

The exclusive power of determining the point of crossing, the terms of installation, operation, maintenance, use and protection of one railroad by another railroad or street railroad, or of highways by railroads or street railroads, is vested in the commission, which may alter or abolish such crossing or require a separation of grades, prescribing the terms upon which such separation shall be made and the proportion in which the expense of alteration or abolition of the crossing shall be divided between the corporations affected and the State, municipality or other public authority in interest.

The commission may, after a hearing and upon its own motion or complaint, find that public convenience and necessity demand the establishment, creation or construction of a crossing of a street or highway over, under, or upon the lines of any public service corporation and may by order, decision, rule or decree require the establishment, construction or creation of such crossing, which shall thereafter become a public highway and crossing.

Following is quoted from the Chairman of the Arizona Corporation Commission:

"We have not been called upon to issue any orders eliminating grade crossings. There has been some work of this character done by agreement between cities and railroads. I will advise you later what the basis of the allocation of the cost has been. Without being able to definitely define the policy of the Commission in the questions you propound, I might state that there are no provisions of law whereby our State would bear a part of the expense of the elimination of grade crossings. On account of the comparatively light highway traffic in this State, we do not anticipate the question will be of very great importance and that there will be no necessity for a hard and fast line of procedure. Generally speaking, it seems proper to the writer to divide the expense of grade-crossing elimination between the public and the railroads. The public expense would be borne in our State by the City or other political subdivision of the State. If other public service corporations were in any way benefited they should, in my opinion, join in the expense, i. e., if electric, gas, water or street railway companies were in any manner benefited by the change, it would be proper to assess a part of the cost against the utility so benefited."

Arkansas.

RAILROAD COMMISSION OF ARKANSAS.

There are no laws in this State in reference to the elimination of grade crossings. As a general proposition the Railway Companies are required to bear the expense of all crossings, and the Railroad Commissions have authority, in certain cases, to designate whether a crossing should be at grade or otherwise. There have been some cases where the expense of crossings have been divided between the railroads and municipalities or street railways, but, as a general proposition, the Railways are required to bear the entire expense.

The St. Louis, Iron Mountain & Southern Railway, the Rock Island, the city, the county and the street railway company apportioned the cost of West Third Street viaduct in Little Rock in the following proportions:

St. Louis, Iron Mountain & Southern	35 per cent.
Rock Island	26 per cent.
Street railway company	19 per cent.
City of Little Rock	10 per cent.
County of Pulaski	10 per cent.

California.

RAILROAD COMMISSION OF THE STATE OF CALIFORNIA.

Chapter 91, section 43, of the Public Utilities Act of 1912, amended by the Legislature of 1917, gives to the Railroad Commission the exclusive power to order construction, alteration, relocation, abolition, etc., of grade crossings and to apportion the expense among the intereseed parties. The Commission is also given power to enforce collection by suit of any part of the expense from the corporation or governmental body to which such expense may be apportioned.

Colorado.

PUBLIC UTILITIES COMMISSION OF COLORADO.

Section 29 of the Public Utilities Act of 1913, amended in 1917, gives to the Public Utilities Commission the power to order construction, alteration, relocation, abolition, etc., of crossings between railroads and highways, and to apportion the cost to the railroad or street railway corporation affected, or between the corporation or corporations and the state, county, municipality or public authority in interest.

In Denver the Alameda Avenue subway, which carries the street with Electric Railway tracks under the tracks of the Santa Fe, the D. & R. G.. and Colorado & Southern, was paid for in the following manner: City 33 1/3 per cent., Railroads 33 1/3 per cent., Street Railway 33 1/3 per cent.

Connecticut.

PUBLIC UTILITIES COMMISSION.

The Pubilc Utilities Commission has general supervision of the matter of elimination of grade crossings between highways and railroads, but the apportionment of the expense is fixed by law. This apportionment varies according to who initiates the project. In case a City or other governmental body petitions for the change, it must pay 25 per cent. of the expense, if the highway existed prior to the construction of the railroad, or 50 per cent. of the expense if the railroad was constructed prior to the opening of the highway. In case the railroad initiates the petition, it bears the entire expense of the work, and it is obligatory that each railroad shall petition each year for the abolition of one grade crossing for every fifty miles of road operated within the state. In case a street railway desires the change in a crossing it may petition on the same basis as the City whose streets it occupies.

Delaware.

DELAWARE HAS NO RAILROAD OR PUBLIC UTILITY COMMISSION.

No reply was received from inquiries addressed to City Engineers, or others, in the state of Delaware, and the only information available is the 1913 report of Railroad and Highway Commission of Massachusetts, which states "the public utility law passed in 1911 by the State of Delaware does not appear to make provision for the elimination of grade crossings, but has a statute, section 116, intended to prevent grade crossings as far as practicable."

Florida.

FLORIDA RAILROAD COMMISSION.

From the information collected, it appears that there is no statute in force in the state of Florida bearing on or regulating the abolition of grade crossings. It necessarily follows, therefore, that any action taken on this subject would be pursuant to voluntary agreement or to the provisions of street franchises granted by municipalities.

No information is available as to any grade separation in this state. We learn, however, that consideration has been given to the separation of grades at two or three points on the Atlantic Coast Line. At one point the question of dividing the expense with the County was considered, and the County officials were agreeable to dividing the expense about on an equal basis, but as the money was not available to do the work, nothing has been done.

Georgia.

RAILROAD COMMISSION OF GEORGIA.

The Secretary of the Railroad Commission of Georgia advises that the Commission has no jurisdiction over grade crossings, and although the Commission has recommended to the Legislature several times that it be given jurisdiction, this has not been enacted into a law up to the present time.

In the City of Savannah, of the two subways constructed, the city bore one-third of the expense; in another case the expense was divided between the Street Railway, the Railroad Company and the City; and in another case the City stood one-half the cost and the Railroad the other half.

Idaho.

PUBLIC UTILITIES COMMISSION.

There appears to be no specific law governing the elimination of grade crossings between railroads and highways. Section 2808 of article 2 of The Idaho Railroad laws, gives railroads broad powers in taking lands necessary for grade crossing elimination work.

In Pocatello, the railroads have borne all the cost of the work, including consequential damages. The cost of removing and replacing paving, walks, etc., has been borne by the abutting property owners, except that portion located on or over carriers' tracks and right-of-way.

Illinois.

PUBLIC UTILITIES COMMISSION OF ILLINOIS.

The Public Utilities Law gives to the Public Utilities Commission jurisdiction over the matter of grade crossing elimination and empowers the Commission to fix the apportionment of the expense in connection with same.

Replies from inquiries sent to several cities indicate that generally the Municipality bears the expense of damages to abutting property and cost of moving drains, sewers, etc., owned by it; the public service corporations bear expense of changing street railway facilities, electric and 'phone wires and poles, gas pipes, conduits, etc., owned by them, and the railroads bear all other expenses. There is some variation in the practice, however, as regards to the cost of paving and cost of changing pipes, poles, etc., owned by the Municipality, these items of expense being borne in some instances by the railroads and in others by the Municipality. None of the replies received indicate that the State bears any part of the expense or that a County bears any part of the cost of work done within the corporate limits of a municipality.

Indiana.

PUBLIC SERVICE COMMISSION OF INDIANA.

Secretary of the above Commission advises as follows:

"There is a specific law granting control of separation of grades to the Public Service Commission of Indiana. There has been no decision of the Supreme Court of Indiana on this law. Chapter 75 of the Acts of 1915 provide certain powers to cities having a population of 20,000. The expense is fixed or apportioned by law, the Railway Companies bearing 75 per cent., the State nothing, the County 25 per cent. and the municipality and public service corporations nothing."

In Indianapolis the Railway Company paid 75 per cent. of the expense of grade elimination, the Street Railway and City 25 per cent.

In Ft. Wayne the Street Railway paid 12½ per cent. of the total cost of some grade separation work done by the Wabash Railroad.

Iowa.

BOARD OF RAILROAD COMMISSIONERS.

Section 2017 of the Supplemental Supplement to the Code of Iowa, 1915, reads as follows:

"Wherever a railroad now crosses an established highway, or when a new railroad crosses an established highway, or when it is desired to locate a new highway across an established railroad, or when it is desired by any citizen of or the board of supervisors of any county or by the township trustees of any township, or by any railroad company operating a railroad in this state, for the safety of the public using such highway, to change, alter, relocate, or vacate an established highway, where same crossed a railroad, and the railroad company and the board of supervisors of the county or township trustees of any township in which such highway crossing is located cannot agree in respect thereto, the board of railroad commissions of this state, upon application of either the board of supervisors or township trustees of any township or of twenty-five freeholders of said county, or the railroad company interested, are authorized and empowered, after hearing upon reasonable notice, to determine the necessity for such crossings, location thereof, whether the same shall be at grade or otherwise, the manner in which the same shall be constructed, maintained, or changed, division of expense thereof, and generally to make such orders in respect thereto as are equitable and just, including the right to require condemnation proceedings to be instituted by the board of supervisors as may be necessary to carry out such order; providing, however, that any portion of such expense that is borne by any city, town, county, state or other public body, shall forever be considered as held in trust by said railroad company receiving same, and no part of the same shall be considered a part of the value of the properties of said railroad company upon which it is entitled to receive a return."

Sections 770, 771 and 773 of the Code of Iowa, 1897, as amended by the Supplement to the Code of Iowa, 1913, and the Supplemental Supplement to the Code of Iowa, 1915, read as follows:

"Sec. 770. Viaducts—when required. Cities having a population of seven thousand or over shall have power to require any railroad company, owning or operating any railroad tracks upon or across any public streets of such city, to erect, construct, reconstruct, complete and maintain, to the extent hereinafter provided, any viaduct upon or along such streets, and over or under such tracks, including the approaches thereto, as may be declared by ordinances of such city necessary for the safety and protection of the public. The approaches to any such viaduct shall not exceed a total distance of eight hundred feet, but no such viaduct shall be required on more than every fourth street running in the same direction, and no railroad company shall be required to build or contribute to the building of more than one such viaduct, with its approaches, in any one year; nor shall any viaduct be required until the board of railroad commissioners shall, after examination, determine the same to be necessary for the public safety and convenience, and the plans of said viaduct, prepared as hereinafter provided, shall have been approved by said board."

Sec. 771. Assessment of damages. That section seven hundred seventy-one of the code of supplement (1902) is hereby repealed and the following enacted in lieu thereof:

"'When a viaduct shall be by ordinance declared necessary for the safety and protection of the public, the council shall provide for appraising, assessing and determining the damages which may be caused to any property by reason of the construction of the same and its approaches. The proceedings for such purpose shall be the same as are provided in case of taking private property for works of internal improvement, and the damages assessed shall be paid by the city out of the general bridge fund, or in cities having a population of twelve thousand or over from any other fund or funds legally available therefor.'"

"Sec. 773. Apportionment of cost—use of—compensation for—repairs. When two or more railroad companies own or operate separate lines of track to be crossed by a viaduct, the proportion thereof, and the approaches thereto to be constructed by each, or the cost to be borne by each, shall be determined by the council. The council shall fix a time and place where it will consider such matters and any objections that may be made to the construction of such viaduct and the approaches thereto. Not less than twenty days' written notice of such hearing shall be given to the company or companies owning or operating the track or tracks over or under which it is proposed to construct such viaduct. Said notice may be served in the same manner and upon the same persons or officers as in the case of an original notice. Such cities shall have power to regulate the use of such viaducts and to authorize or forbid the use thereof by street railway companies and to require the payment of compensation for such use. After the completion thereof, any revenue derived therefrom by the crossing thereon of street railway lines shall constitute a special fund, and shall be applied in making repairs to such viaduct. One-half of all ordinary repairs to such viaduct or its approaches shall be paid out of such fund, or be borne by the city, and the remaining half by the railroad company; and if the track of more than one company is crossed, the costs of such repairs shall be borne by such companies in the same proportion as was the original cost of construction."

The viaduct carrying Seventh St. over the tracks of various Railways in the city of Des Moines will be paid for by the Railway Companies, the Street Railway, which will use the viaduct, assuming that portion of the cost covering the excess capacity of the Bridge required on account of its traffic.

Reply to inquiry sent to City Engineer, Des Moines, indicates that the City bears the consequential damages to abutting property; cost of paving, walks, etc., is assessed to abutting property owners; Street Railway Co. and other public service corporations bear expense of changing facilities owned by them and the railroads bear all other expense. There is no information at hand to indicate that the State shares in the expense, or that a county shares in the expense of such work within the corporate limits of a municipality.

Kansas.

PUBLIC UTILITIES COMMISSION.

There is no law concerning the abolition of grade crossings nor the apportionment of cost incident thereto.

The following is quoted from the American Railway Engineering Association Bulletin, No. 171, dated November, 1914, page 185:

"Wichita, Kansas. At one subway in some track elevation work in which there is a street railway, the street railway company paid not only for the changes in its tracks, etc., and the pavement in and between its tracks, but pays for the cost of the substructure of the street which it occupies, including the pavement and column pedestals, and the excavation for same. There is a mutual agreement here between the railway company and the city and the street railway company that, in any future track elevation, one-third will be paid by each party."

Kentucky.

KENTUCKY RAILROAD COMMISSION.

In the absence of any information from the above commission, there is quoted below from report of the City Engineer of Louisville, Ky.:

"There is no State or Municipal law in Kentucky governing the apportionment of costs of this character, and consequently I am unable to give you the information in the form that you desire it. However, it may be of interest to your committee to know the procedure under which grade crossings have been eliminated in Louisville.

"All work done to date has been arranged by mutual agreement between the Railroad and the City, each bearing a portion of the expense. In the last work done locally, however, no portion of the expense was paid by the city, owing to the fact that the reconstruction of the Railroad Company's bridge over the Ohio River and the relocation of its yards, the railroad was forced to elevate its tracks to avoid prohibitive grades. Under these circumstances, the city did not feel that it was called on to bear any portion of the expense, since the work was not done on the city's initiative. Some part of the cost of this work was paid by the Street Railway Company, under a private agreement between that company and the railroad. On all work done prior to the above mentioned job, the cost has been divided between the city and the railroad, by mutual agreement, on the following basis:

"The cost of grading, retaining walls, abutments, super-structure, paving, drainage, and in fact all items of expense, except consequential damage to abutting property, was borne entirely, in so far as the approaches are concerned, by the city. The same expense beneath the railroad tracks were borne entirely by the railroad. That is—the city paid for the entire cost of approaches, and the railroad company for the subway proper. In addition, the city paid the entire property damage."

It appears that by apportioning the expense, as above indicated, the City has borne about 65 per cent. of the total cost.

Louisiana.

RAILROAD COMMISSION OF LOUISIANA.

Information available indicates that there is no general law in Louisiana governing the elimination of grade crossings between railroads and highways or streets, and that the Railroad Commission has no jurisdiction in matters of this kind.

In New Orleans two viaducts have been constructed at the joint expense of the Street Railway Company and the Railroads.

Maine.

PUBLIC UTILITIES COMMISSION.

The following is quoted from the Chairman of the above Commission:

"Public Utilities Commission has jurisdiction over the elimination of grade crossings and no city, town or plantation has any jurisdiction over the matter whatever.

"Chapter 147 of the Public Laws of 1913 gives to this Commission the authority upon petition by the municipal officers of a city or town or the railroad interested to change the approaches or the manner of crossing or entirely eliminate a grade crossing by causing a way to pass at the side of the railroad.

"The same law which gives us authority to act fixes the division of the expense at 65 per cent. to the railroad, 25 per cent. to the State, and 10 per cent. to the town.

"The division of the expense is mandatory and the auditing of bills for such elimination or change of method of crossing is left to the Public Utilities Commission.

"No city or town in our State has any authority whatever over the matter of the elimination of grade crossings or the expense incident thereto.

"There is no contemplated legislation and no case pending which will in any way change or modify the existing law."

Maryland.

PUBLIC SERVICE COMMISSION.

The Public Service Commission Law of 1910 gives the Public Service Commission general supervision over all railroad matters, but does not specifically cover the matter of grade crossing elimination nor apportion the cost of such work.

In Baltimore, the city usually has borne the expense of changing sewers, pipes, poles, wires, etc., owned by it, and the cost of paving outside the right-of-way limits; the Street Railway Co. and other public service corporations have borne the expense of changing their tracks, poles, wires, conduits and other facilities; and the railroads usually have borne all other items of expense, including consequential damages to abutting property.

There is no information at hand indicating that the State shares in the cost of grade crossing elimination work, or that a county shares in the expense of work within the corporate limits of a municipality.

Massachusetts.

PUBLIC SERVICE COMMISSION.

The Railroad Laws of Massachusetts provide for the appointment of a special commission in each case of grade crossing elimination work, whose duties shall include the apportionment of the cost among the various parties interested. The law provides that the railroads shall pay 65 per cent. of the entire expense; a street railway may be required to pay an amount not exceeding 15 per cent. of the total expense; and the remainder shall be divided between the State and the local governmental body, but not exceeding 10 per cent. shall be paid by a municipality.

Michigan.

MICHIGAN RAILROAD COMMISSION.

The Railroad Laws of Michigan give to the Council of a Municipality or corresponding governmental body of townships, counties, etc., the right to enter with railroads, railways and others interested into agreements covering the matter of grade crossing elimination and the apportionment of the cost of such work. These agreements are subject to approval of the Railroad Commission, which body also has power to order work and apportion cost in case agreements cannot be reached by parties interested.

In Detroit, usually the City bears the consequential damages to abutting property; the Street Railway bears a part of the cost of changing its facilities; the other public service corporations bear the cost of changing their pipes, poles, wires, etc.; and the railroads bear all the other expense, including paving, walks, etc.

Information at hand indicates that the State does not share in the expense of this work.

Minnesota.

MINNESOTA RAILROAD AND WAREHOUSE COMMISSION.

There appears to be no specific laws governing the matter of elimination of grade crossings between highways and railroads. The general laws contain provisions which are held by the Commission to put all expense in connection with railroad crossings upon the railroads.

The usual manner of eliminating grade crossings and apportioning the cost is by agreement between the local governmental body and the railroads. The City sometimes takes care of the paving; the Street Railway and other public service corporations usually bear the cost of changing their tracks, poles, pipes, etc.; and the railroads usually bear all other items of expense, including consequential damages to abutting property.

There is no information at hand to indicate that the State bears any part of the expense of this work. In the City of Duluth, the County has borne a portion of the expense, the amount varying with the will and pleasure of the Commissioners.

Mississippi.

MISSISSIPPI RAILROAD COMMISSION.

The only law in this State having reference to grade crossings is Section 4053, Code of 1906, which provides:

"Where a railroad is constructed so as to cross a highway, and it be necessary to raise or lower the highway, it shall be the duty of the railroad company to make proper and easy grades in the highway, so that the railroad may be conveniently crossed, and to keep such crossings in good order; and it shall be the duty of the company to erect and keep in order all bridges on any highway, at such points as bridges may be necessary to cross the railroad; and any company which shall fail to comply with these provisions shall forfeit the sum of one hundred dollars, to be recovered by action in the name of the county in which the crossing or bridge is situated."

Section 3369, Code of 1906, provides:

"To regulate the crossings of railways and street-railroad tracks, and provide precautions and prescribe rules regulating the same; and to regulate the running of street-railroads or cars, and railway engines, cars and trucks within the limits of the city, and to prescribe rules relating thereto and govern the speed thereof; and to make any other and further provisions, rules and regulations to prevent accidents at crossings and on the tracks of railroads, and to prevent fires from engines and to require railroad companies to erect viaducts over or gates across their tracks at the crossing of streets."

Under Section 4053, it would seem that the public authorities would have the power to impose the whole expense on the railroad companies. Just what powers the municipalities would have under Section 3369 as to apportioning the expense has not yet been determined, as no case under this section has been carried to the Supreme Court. There have been several attempts on the part of the legislature to pass a law fixing the proportionate amount that the municipality and the railroad company should each pay, but these have always been ineffectual, and so far no law has been passed.

In Vicksburg, by agreement viaducts have been constructed in which the railroad bore the expense of the viaduct proper and the paving on its right-of-way; the street railway company and other public service corporations bore the expense of changing their facilities and the City bore the expense of paving not on carrier's right-of-way, the cost of moving pipes, poles, wires, etc., owned by the City and all of the consequential damages to property.

There is no information at hand to indicate that the State shares in the expense of grade separation work.

Missouri.

PUBLIC SERVICE COMMISSION.

Section 50 of Public Service Commission law of 1913 empowers the Public Service Commission to order the elimination of grade crossings and to apportion the expense.

The practice seems to be that the Railroads pay the physical cost of structure, except lighting fixtures. Where structure is to be occupied by a street railway, said company frequently participates in expense; city generally takes care of consequential damages.

Montana.

RAILROAD AND PUBLIC SERVICE COMMISSION.

There appears to be no law covering the abolition of grade crossings, nor the apportionment of the expense incident thereto.

At Great Falls two viaducts are being built and one has been finished, and the City Engineer of that City advises as follows:

"Our experience to date has been that carrier has borne all cost of constructing subways and overhead crossings with the exception of new pavements and moving private property."

Nebraska.

NEBRASKA STATE RAILWAY COMMISSION.

The following is quoted from the Chairman of the above Commission:

"The style of the Nebraska Commission is Nebraska State Railway Commission. There are a number of statutes which have been passed from time to time, providing for plans and specifications of public crossings and the maintenance and upkeep of the same, which will be found in our statutes. However, when people by a constitutional amendment created the Nebraska State Railway Commission, jurisdiction of rates, service and general control of all common carriers were placed with the Commission. I take it that unless our legislature specifically legislate in matters of rates and service and general control the Commission has full and complete power over the subject matter.

"I believe that the Commission has full jurisdiction of all crossings in the state of Nebraska, both public and private, including those in all cities of the metropolitan class, first and second class, and villages, private farm crossings and public highway crossings, whether they be overhead crossings, grade crossings or sub-crossings. I say this having fully in mind Section 6042 of Article 6, Chapter 67, Compiled Statutes of Nebraska for 1913, which provides:

"'CROSSINGS, WHEN PERSON OWNS LAND ON BOTH SIDES—When any person owns land on both sides of any railroad, the corporation owning such railroad shall, when required so to do, make and keep in good repair one causeway or other adequate means of crossing the same.'

"This statute was interpreted by our own Supreme Court, in which there are certain dissenting opinions, in the case of O. & R. V. Ry. Co. vs. Severin, and will be found in 30 Nebraska 318. This opinion was rendered by the Supreme Court long before the Nebraska State Railway Commission had been created by the constitutional amendment, and I take it that the statute is obsolete by reason of the constitutional amendment which created the Railway Commission. Said constitutional amendment placed in the hands of the Railway Commission jurisdiction of rates and service and general control.

"My theory is that you cannot consider service without at the same time having in mind facilities. Crossings and crossing facilities certainly go directly to the public safety, which matter was placed in the hands of the Railway Commission by statute. Crossings and crossing facilities also go directly to the safety of people riding on the trains; therefore, these facilities affect the service. Without going into a long discussion, I am frank to say that I am of the opinion that the Railway Commission has full jurisdiction of all crossing questions in the state of Nebraska."

Following is quoted from American Railway Engineering Association Bulletin No. 171, dated November, 1914, Page 186:

"South Omaha, Neb. The Union Pacific Railroad Company built a viaduct to carry a street over its tracks. This viaduct cost exceeding $160,000 and 10 per cent. of the cost was paid by the street railway company in addition to the cost of paving in and between its tracks, as provided for in its franchise."

Nevada.

RAILROAD COMMISSION OF NEVADA.

Section No. 7, Paragraph 2, of the Railroad Commission law reads as follows:

"The Commission shall also have full power to investigate the physical condition of all railroad property, and, in the interest of safety or service, shall have power to determine and order repairs, reinforcements or reconstruction of property, including buildings, tracks and equipment; also the power to determine and order the use of safety appliances in the interests of employes and the traveling public, such as crossing-gates, flagmen, bells, devices, etc., interlocking plants at railway crossings and all other modern safety devices. The Commission shall have full power to determine and order the manner in which any railroad, street railway, steam or electric railway, or other common carrier, may cross another railroad, street railway, whatever the motive power, at grade, or above or below grade, and shall prescribe the safety appliances and regulations that should be adopted at such crossings or at existing grade crossings or railroads, steam, electric or other motive power railways for the protection of the public and the prevention of accidents. The Commission shall have the power, whenever, in its judgment, it shall appear wise and proper to do so, to authorize and direct reasonable changes in train schedules and train service."

There has been very little work done in this state in connection with the abolition of grade crossings, and, as a consequence, no information is available concerning the practice.

New Hampshire.

PUBLIC SERVICE COMMISSION.

The cities or towns in which crossings are located have authority to require elimination, and the railroad may appeal to the Commission from the vote of the municipality requiring such elimination. (See Public Statutes, Chapter 159, Sections 15, 16 and 17.)

There is no provision regarding division of expense. If the Commission orders elimination, it is presumed by the Commission that the railroad will bear the expense, unless the municipality and the railroad enter into a voluntary agreement for the apportionment.

New Jersey.

BOARD OF PUBLIC UTILITIES COMMISSIONERS.

Chapter 57 of the Laws of New Jersey, effective March 12, 1913, provide that Commissioners may order elimination of crossings, expense to be borne by Railroad, except where Street Railways are invovled, in which case not to exceed 10 per cent. may be ordered borne by the Street Railway. Public Service Corporations bear entire expense of changing their facilities.

Data available indicates that at Newark two important pieces of grade elimination have been completed in the last 18 years on the Lackawanna and Pennsylvania Systems. In both cases, by agreement, the City paid the railroad the sum of $600,000, and paid one-half of the property damages. The City's share of the total cost was in the neighborhood of 20 per cent.

New Mexico.

STATE CORPORATION COMMISSION.

There appears to be no specific law covering the abolition of grade crossings, and no information is available concerning any work of this nature that has been done.

New York.

PUBLIC SERVICE COMMISSION.

Sections 91, 92, 95, 97 and 99 of Chapter 481, Section 93 of Chapter 484 and Section 94 of Chapter 240 provide that upon petition from Municipalities the Commission may order separation of grades on the following basis of expense:

Where new railroads are constructed across existing streets, Railroads bear 100 per cent.

Where new highway is constructed across existing railroads, Railroads bear 50 per cent. and Municipalities 50 per cent.

Where changes are made in existing structures, excepting where crossing is located within incorporated villages not exceeding 1,200 inhabitants, Railroads bear 50 per cent., State 25 per cent. and County 25 per cent.

Where changes are made in existing structures located within incorporated limits not exceeding 1,200 inhabitants, Railroads bear 50 per cent., State 25 per cent. and Municipalities 25 per cent.

Where State highway is involved, Railroads 50 per cent. and State 50 per cent.

Where County highway is involved, Railroad 50 per cent.; State, County and Municipality 50 per cent., divided in same proportion and manner as construction or improvement of such highway is apportioned.

Consequential damages, expense of changing sewers, water pipes, etc., are included in joint account and distributed on proper percentages. Public Service Corporations bear expense of their own facilities affected.

Legislature appropriates $100,000.00 annually for grade crossings, and if this amount is not expended, the unexpended portion is used to reduce the next year's proportion. The maintenance of existing structures is on the basis of: overhead highway, framework and abutment by railroad, railroad approaches by Municipalities, under grade crossings, bridge abutments by railroads, subway and approaches by Municipalities.

The Cities of Buffalo, Syracuse and Niagara Falls have special laws.

Buffalo: Department of Public Works petitions the State Public Service Commission, which orders manner and method of crossing expense being borne 50 per cent. by Railroad and 50 per cent. by City. Expense generally includes paving across Railroad's right of way.

Syracuse: City may order elimination of crossings subject to approval of Public Service Commission, expense being borne 50 per cent. by Railroad, 25 per cent. by City and 25 per cent. by State—expense includes all changes.

Niagara Falls: No information available.

North Carolina.

CORPORATION COMMISSION.

In the absence of any information received from the above Commission, there is quoted below information secured from Assistant General Counsel, Mr. P. A. Wilcox, of the Atlantic Coast Line Railroad Company:

"I beg to call your attention to the attached copy of letter from Mr. W. A. Townes, Attorney, in which he outlines the law on the subject, rules of the Corporation Commission of this State, and makes reference to certain decisions in cases from this State, where the question has been touched upon directly or collaterally. However, there seems to be no statute or regulations bearing directly on the subject, and the separation of grade crossings between Railroad and Highway is a matter of agreement."

I quote below letter above referred to from W. A. Townes, Attorney:

"Replying to your request of November 9, 1917, for advice as to the Law in North Carolina governing this subject, I will state that Sections 2567 (5 and 6) to 2573, inclusive of the Revisal of 1905, cover generally the subject of the rights of railroads to cross public highways. Section 2601 of the Revisal of 1905 covers crossing of private roads.

"Section 1097 of the Revisals of 1905 gave authority to the Corporation Commission of North Carolina on this subject generally, same being an act originally enacted in 1899, Chapter 164. This section was again amended and re-enacted in part in the Session of 1911, Chapter 197, and the extra Session of 1913, Chapter 63, and the law as now in force on this subject reads as follows:

"'1097a. Safety and convenience of passengers and patrons; block systems; highway crossings; railroad crossings; crossing bridges.

"'In addition to the powers already conferred upon and possessed by the North Carolina Corporation Commission it shall have power:

"'(a) To make any necessary and proper rules, orders and regulations for the safety, comfort and convenience of passengers, shippers or patrons of any public service corporation, and to require the observance of the same by the company and its employes.

"'(b) To require any railroad company to install and put in operation and maintain upon the whole or any part of its road a block system of telegraphy or any other reasonable safety device, but no railroad company shall be required to install a block system upon any part of its road upon which it is not operated as many as or more than eight trains each way per day.

"'(c) To require the raising or lowering of any tracks or highways at any highway or railroad crossing, and to designate who shall pay for same; and when they think proper, partition the cost of abolishing grade crossings and the raising or lowering of said track or highway among the railroads and municipalities interested.

"'(d) To require, when public safety demands, when and in case two or more railroads now cross or may hereafter cross each other, at a common grade, or any railroad crosses any stream or harbor by means of a bridge, to install and maintain such a system of interlocking or automatic signals as will render it safe for engines and trains to pass over such crossings or bridge without stopping, and to apportion the cost of installation and maintenance between said railroads as may be just and proper. (1907, c. 469; 1911, c. 197; Ex. Sess. 1913, c. 63.)'

"As far as I can locate, this Section 1097a (c) has not been passed upon by the Supreme Court of North Carolina, but the original Section 1097 was referred to in the case of the Atlantic Coast Line Railroad Company vs. City of Goldsboro, 155 N. C. 356, 71 S. E. Reporter 514, affirmed by the Supreme Court of the United States, 232 U. S. 548, 58, L. Ed. 721. This case discusses this subject generally, and you will note holds that this statute was not in derogation of those conferred in the charters of towns and cities, but is supplementary thereto.

"Chief Justice Clark, in a concurring opinion in the case of Herndon vs. Durham & Southern Railway Company, 161 N. C. 650, 77 S. E. R. 683, held it was a policy of the Law to favor under-passes and overhead bridges and to abolish grade crossings, but this I think was merely obiter dicta.

"So far as I can locate, no general rules or regulations have been prescribed by the North Carolina Railroad Commission under authority of Section 1097a (d)."

North Dakota.

BOARD OF RAILROAD COMMISSIONERS.

The following is quoted from Rate Expert and Statistician, J. A. Little, of the above Commission:

"The power to regulate this matter is covered by Sections 4689-92 of the Revised Code 1913. We have no law which fixes the division of expenses of grade crossings elimination as between the railroad company and minor civil divisions. Our law does not provide for the apportionment of expense in this connection between the public and the carrier; leaving the entire burden to be borne by the railroad company.

"No city in this state has a charter which gives it special powers over grade crossings separation and there is no legislation contemplated or case now pending which will have a bearing on the construction of the present law.

"A comparatively recent case which was decided by our Supreme Court held that the Board of Railroad Commissioners had power to require the separation of grades on public highways.

"This case involved a highway crossing over the C. M. & St. P. Railroad Company at Marmarth."

Ohio.

PUBLIC UTILITIES COMMISSION OF OHIO.

The Public Utilities Commission of Ohio has no jurisdiction in the matter of grade crossing elimination. The power to deal with matters of this nature is vested in Municipalities.

Section 8883 of the general code, which was amended May 10, 1910, reads as follows:

"The cost of constructing the improvement authorized, including the making of ways, crossings of viaducts, above or below the railroad tracks and the raising or lowering of the grades of the railroad tracks and sidetracks for such distance as may be required by such municipality and made necessary by such improvement, together with the cost of land or property purchased or appropriated and damages to owners of abutting property or other property, shall be borne, 35 per cent. by the municipality and 65 per cent. by such railroad company or companies. The municipality shall have a right of action against any such railroad company for the recovery of the 65 per cent. and such costs payable by it with interest from the time they become due. Such municipality and railroad company may agree as to what part of the work shall be done by the railroad company and also fix the amount to be allowed or credited to the company for doing the work. Such railroad company shall be entitled to deduct from its 65 per cent. of the cost of the improvement the expense incurred by it in the change of grade required by the municipality or made necessary by it under such specifications, but only in case the amount of expense has been agreed upon in writing between the municipality and the railroad company. If the amount of work done by the company, or made necessary by reason of such change of grade on lowering or raising its tracks, exceeds 65 per cent. of the cost of the improvement, then it shall have the right to recover the amount with interest in excess of 65 per cent. of the expenses in an action at law against the municipality."

Oklahoma.

CORPORATION COMMISSION.

Will say there is no authority for compulsory separation of grades, except by the authorities of incorporated cities and towns and by the Legislature as to highways outside of such incorporated communities.

The Chairman of the Corporation Commission advises as follows:

"It has not been judicially determined just what jurisdiction the Corporation Commission has in reference to the matter of elimination of grade crossings and railroads. In the case of A. T. & S. F. Ry. Co. vs. State, Supreme Court No. 6198, pending on motion for rehearing, the Court held that the matter of constructing viaduct over the Santa Fe in the City of Guthrie was a matter for the local authorities to regulate. Under all the court decisions so far, the local authorities in incorporated cities and County Commissioners and town boards outside of incorporated cities, are the bodies which have jurisdiction over the matter of crossings.

"The power exercised by the Corporation Commission over crossings is found in Section 18, Article 9, Constitution. The following cases will give you the law in reference to the matters you ask about: A. T. & S. F. Railway Company vs. State ex rel, West, 40 Okla. 411, 138 Pac. 1026; St. Louis-San Francisco Railroad Company vs. Love et al., 29 Okla. 523, 118 Pac. 259; A. T. & S. F. Railway Company vs. State et al., 28 Okla. 797. For further reference to road law see Chapter 173, Session Laws 1915. A letter addressed to Hon. Geo. Noble, State Highway Commissioner, will secure for you a copy of this law.

"The case of A. T. & S. F. Ry. Co. vs. State et al., Supreme Court No. 6198, now pending on rehearing, may determine the jurisdiction of the Corporation Commission over railroad crossings."

The City Engineer of the City of Tulsa advises as follows:

"In as much as the improvements heretofore, as regards subways and viaducts, have followed lines originally contemplated, there has been no tearing out of old improvements, and that problem has not been as yet reached. In a general way, the railroads pay for all improvements within the right-of-way lines, while the City assumes the cost of approaches, paving, drainage, damages, etc., external to the right of way, either by direct payment, or by assessing a portion or all the cost to the adjoining property in proportion to benefits.

"In order to determine the street grades, ordinances are passed and public utilities (gas, water, poles, conduits, sewers, etc.) are required to be constructed to conform, and the city is in no case liable for relaying or revising the same unless a change of grade is made, in which case they become liable for the full cost of the improvement, due to the change.

"The question of seniority of street railways and railroad tracks depends entirely on the franchise under which they operate. We never encountered two that were identical in their provisions.

"The County bears no part in municipal improvements, as applied to railroad crossings.

"The above discussion applies more particularly to subways than viaducts in this city, as the only viaducts of any length—330 feet—steel construction—was built under special agreement, both with regard to apportionment of cost and maintenance, by the City of Tulsa, the street railway and the railroad company; the railroad's proportion being about

60 per cent. of the cost of the work actually within the right of way (which was about 300 feet wide on the angle crossed)."

Oregon.

PUBLIC SERVICE COMMISSION OF OREGON.

Chapters 228 and 429 of the Laws of Oregon for 1917, and Chapter 275 of the Laws of Oregon for 1913 have reference to the question of grade crossing elimination.

In these we find that the Commission has power to order grade separation and to apportion the expense, excepting in Cities having a population of 100,000 or over.

The only cases of grade separation are in the City of Portland, which does not come under the Commission's control, as population is in excess of 100,000. In this City the separation of grades is made on the basis of Railroads bearing entire expense of any changes in their own tracks and the balance of the expense, including approaches, sidewalks, sewers, wire lines, consequential damages, Public Service Corporations, etc., is divided 60 per cent. to the Railroads, 20 per cent. to the City and 20 per cent. to a local benefit district which is organized in connection with the work. The Railroads' portion of 60 per cent. includes all Railroads and Street Railways, and the division of this percentage to be borne by each must be decided by them within 30 days of order for the work.

Pennsylvania.

PUBLIC SERVICE COMMISSION.

The Public Service Company Law creating or establishing the Public Service Commission, made effective January 1, 1914, gave certain powers of this body with reference to grade crossing question. These laws were amended by the passage of two acts by the last Legislature, one of which amends Section 12 of Article 5 of the Public Service Company Law so as to authorize the Public Service Commission to establish, lay out and open public highways in boroughs or townships in order to provide access to crossings which may be established, relocated or constructed in accordance with the orders of said commission and to authorize said commission to abandon and vacate public highways which may become unnecessary. This act was passed in order to enable the Commission to so lay out streets and roads as to make them all converge at one crossing instead of a number of crossings in order to prevent the construction of many unnecessary and expensive over and under grade crossings.

A portion of the other act referred to is quoted below:

"Whereas, The control of this matter has been placed in the hands of the Public Service Commission of the Commonwealth of Pennsylvania with authority to apportion the costs, including damages to adjacent property owners among the public service companies, municipalities and the Commonwealth, and

"Whereas, No funds have been specifically appropriated by the Commonwealth for the purpose of the payment of the cost of such improvements, including the compensation for damages which the owners of adjacent property may sustain, therefore,

"Section 1. Be it enacted by the Senate and House of Representatives of the Commonwealth of Pennsylvania in General Assembly met, and it is hereby enacted by the authority of the same that the sum of two hundred thousand dollars ($200,000), or as much thereof as may be necessary, be, and the same hereby is specifically appropriated to the Public Service Commission of the Commonwealth for the two (2) fiscal years commencing on the first day of June, one thousand nine hundred and seventeen, for the purpose of the payment of such proportion of the costs, including the compensation for damages to adjacent property taken, injured or destroyed in the construction, relocation, alteration or abolition of any crossing of the tracks of public service companies over (public) State highways in this Commonwealth, which shall be determined by the Public Service Commission of the Commonwealth of Pennsylvania to be paid by the Commonwealth.

"Section 2. The amounts payable hereunder shall in each instance be paid by the State Treasurer on a warrant drawn by the Auditor General upon the presentation to that officer of a statement by the chairman of the Public Service Commission of the Commonwealth of Pennsylvania, setting forth the amount determined to be paid as aforesaid, which statement shall certify that the amount mentioned therein is either the entire amount assessed against the Commonwealth or the portion of said entire amount due and payable at the date of said statement.

"Section 3. In no case shall the Public Service Commission of the Commonwealth of Pennsylvania authorize the payment out of the amount herein appropriated of more than twenty-five per centum (25 per cent.) of the cost, including the compensation to adjacent property owners of any construction, relocation, alteration or abolition of a crossing."

The Acts, above referred to, having been passed in 1917, no data, is available as to the practice under these.

Prior to this time, the matter was handled under an Act of the Assembly of the State of Pennsylvania, approved June 9, 1874, which authorized cities and towns of the State to enter into contracts with railroad companies with a view of abolishing grade crossings; and we find that the City of Philadelphia has an agreement with the various railroad companies, under authority of an ordinance of Councils approved, 1914, whereby crossings are to be eliminated, the expense of which amounts to about twenty-five millions of dollars. Approximately 50 per cent. of this is to be paid for by the City, and the remainder by the Railway Companies.

Rhode Island.

PUBLIC UTILITIES COMMISSION.

Section 48 of Chapter 215 of the Rhode Island laws provides that the town council of any town wherein a turnpike or highway crossing crossed by a railroad on the level therewith is situated may request the corporation owning a railroad to raise or lower such turnpike or highway, if it is of the opinion that it is necessary for the security of the public that such action be taken. If the corporation neglects or refuses so to do, the town council may apply to the railroad commission, now the Public Utilities Commission, for decision upon the reasonableness of the request, and if it is decided that such lowering or raising of the grade is necessary, the corporation shall comply with the decision. Within thirty days after such decision either party may petition the Supreme Court for relief, and the court has full power to finally decide the question.

The cost and expense of making the change of grade shall be borne by the railroad corporation and the town in such proportion as may be decided by the court.

If, after the decision of the court, or if, having taken no appeal from the decision of the commission, the corporation unreasonably neglects or refuses to change the grade, the town council may proceed to make such change, and may in an action against the corporation recover all charges and expense occasioned by making the alteration.

In January, 1912, a special act was passed for the elimination of certain grade crossings in Pawtucket and Central Falls by a special grade crossing commission. When this work is done the expense will be apportioned, 65 per cent. to the railroad corporations and 17½ per cent. to each of the cities.

Certain grade crossing work has been done in Providence, and on this the railroad company pay 66⅔ per cent. and the City 33⅓ per cent. of the cost of grade crossing elimination.

South Carolina.

RAILROAD COMMISSION OF SOUTH CAROLINA.

The following is quoted from the Secretary of the above Commission:

"I beg to advise that there is no law in South Carolina governing the apportionment of the cost of elimination of crossings of highways and railroads at grade.

"The Railroad Commission of South Carolina has endeavored for several years past to have such a law enacted, and in their last report to the Legislature, 1916, under the subject of the Elimination of Grade Crossings, they stated:

"'We desire to call your honorable body's attention to the fact that, while having authority over grade crossings, the Commission has no power to prorate expenses when these improvements are ordered. This want of authority often causes delay, and is a source of annoyance to the railway companies against whom the order is directed, to the Commission, and to the interested public.'

"It is the purpose of the Commission to again call the attention of the Legislature to the importance of enacting such a law."

In our further investigation, we have the following communication from P. A. Wilcox, Assistant General Counsel of the Atlantic Coast Line Railroad Company:

"I beg to call your attention to attached copy of letter from F. L. Willcox, Division Counsel, under date of the 11th instant, in which he advises there is no law in this State, under which it is probable to adjust the division of costs between the Railroad Company and the other parties in interest. I might add, in discussing the laws of this State, that this Company has recently entered into an agreement with the authorities of the City of Florence, South Carolina, for the construction of an underpass in one of the public streets of that City, and the agreement, generally speaking, provides that the Railroad Company shall bear the cost of the superstructure, while the City agrees to provide for all necessary drainage, do all necessary grading, and bear the cost and expense of paving and sidewalks. This is the only case I know of in South Carolina of separation of grade crossing between a railroad and a highway."

South Dakota.

BOARD OF RAILROAD COMMISSIONERS.

An Act passed by Legislature (Chapter 126) approved March 2, 1909, empowers the Mayors and Councils or Board of Commissioners to require by ordinance Railroad Companies to erect, construct, reconstruct, complete and keep in repair any viaduct or viaducts upon or along such street or streets and over or under such track or tracks, including the approaches of such viaduct or viaducts as may be deemed and declared necessary for the safety and protection of the public, subject to the reversal by the Board of Railroad Commissioners. The Act empowers the Mayor and Council or Board of Commissioners to apportion the expense as between two or more Railroads, but also provides that the City shall pay the consequential damages.

Tennessee.

TENNESSEE RAILROAD COMMISSION.

The State Highway Engineer of the Department of Highways writes as follows:

"Replying to your letter addressed to B. A. Enloe, Chairman, Tennessee Railway Commission, which has been referred to me for answer, will say that we have no laws in the State of Tennessee for the elimination of grade crossings. The elimination of grade crossings is taken up with the common carriers by the City Commission, or Board of Aldermen, and outside of cities with the various road officials of the county in which the crossings are located, and, as a rule, the cost of the elimination of these crossings is fixed by agreement between the parties. There is no law in the State of Tennessee, as far as I am advised, bearing upon the subject."

The apportionment of the expense of grade elimination in various cities in this State has been as follows:

Memphis: In elimination of four crossings, Railway 69 per cent., City 24 per cent., Street Railway 7 per cent.

Chattanooga: In elimination of McCallie Avenue, Railways 50 per cent., County 25 per cent., Street Railway 25 per cent.

Viaduct rebuilt and cost distributed approximately, viz.: Railways 70 per cent., City 20 per cent. and Street Railway 10 per cent.

Nashville: Street Railway 25 per cent. of the entire cost in several instances.

Knoxville: Park Avenue Viaduct, City 20 per cent., Mayor and Council 20 per cent., Knoxville Light & Power Co. 29 per cent. and Southern Railway 31 per cent.

Asylum Avenue Viaduct, L. & N. R. R. 6 per cent., Southern Railway 12 per cent., City of Knoxville 82 per cent.

Oak Street Viaduct, Railroad Company did grading on R. of W., City constructed at their expense and maintained viaduct.

Gay Street Viaduct, E. T. & V. G. R. R. 31 per cent., City Street Railway 6 per cent., City 63 per cent.

Texas.

RAILROAD COMMISSION.

There is no general law governing the elimination of grade crossings, a bill introduced in the last Legislature having failed to pass.

Some work has been done in the State under agreements resulting from actions by cities to require separation of grades of tracks and streets. Information from cities indicate that the State does not bear any expense of this work and that counties do not share in cost of work within the limits of a municipality.

City Engineer of Dallas advises that a tentative agreement now exists between the City and one of the more important railroads, under which it is proposed to elevate the tracks of the carrier through the City and provide under crossings of all streets. This agreement provides that the entire expense for the work shall be borne by the Railroad Company with the exception of abuttal damages incurred on account of changing the grade of the streets.

Utah.

Utah appears to have no special provision of law as to railroad and highway crossings other than a statute that no railroad shall use any road, street, alley or highway within any city, county or town except with the consent of the authorities of such city, county or town as provided by law; provided that this section shall not be construed to prevent railroads from crossing at right angles, or as nearly as may be, any street, alley, or highway across which its located line may pass.

City Engineer of Salt Lake City advises that the Carriers bear all expense for grade elimination, except consequential damages, which is decided by the Court, also the cost of changing sewers, drains, wires, etc., which expense is borne by city and public utility corporations.

Vermont.

PUBLIC SERVICE COMMISSION.

The Commission has power to order elimination or separation of grade crossings, the apportionment of expense being fixed by law as follows:

Where there is an existing crossing:

Railroads	65 per cent.
State	25 per cent.
Municipality	10 per cent.

Where new highway crosses over existing tracks:

Railroads	60 per cent.
State	25 per cent.
Municipality	15 per cent.

Railroads are required to eliminate one crossing for each 80 miles, or fraction greater than 40 miles, during each year, the order of elimination to be determined by the Railroad Commission. In case of failure to so eliminate crossing at the rate of one each year, the number not so eliminated shall be added to next year's allotment. The expenditure by the State for their cost is limited to $25,000.00 per annum.

Virginia.

STATE CORPORATION COMMISSION.

The following is quoted from the Chairman of the above Commission:

"I can find no construction of our statute with reference to grade crossings involving the point upon which your inquiry is made. So far as this Commission is concerned it has always taken the position that it will order work to be done, but that the apportionment of expense in connection therewith must be determined elsewhere."

Washington.

PUBLIC SERVICE COMMISSION.

Municipalities have jurisdiction and power to order separation or elimination of grade crossings within corporate limits and Public Service Commission has same power outside corporate limits. Neither body has power by law to apportion expense unless confirmed by Supreme Court.

The practice varies from 50 per cent. to Railroads and 50 per cent. to Municipalities to 100 per cent. of expense to Railroads with exception of consequential damages, which has been borne by Municipalities.

West Virginia.

There appears to be no general statutes regulating the apportionment of the cost of elimination of grade crossings between highways and railroads.

Wisconsin.

RAILROAD COMMISSION OF WISCONSIN.

The Railroad Commission of Wisconsin has authority, whenever a petition is lodged with it by the common council of any city, the village board of any village, the town board of any town within which the crossing is located, or whenever it is so lodged by any railroad company, after notice and hearing, to reach a determination as to alterations of such grade crossings, or substitution of another crossing at grade, etc., and the commission has the authority to fix the proportion of the cost and expense of such alterations or removals to be paid by the railroad companies.

Another provision authorizes the commission to take the initiative when in its opinion public safety requires an alteration of any street or crossing at grade by any railroad.

The secretary writes:

"In regard to the Wisconsin practice as to the distribution of the cost of grade separation; the cost of grade separation is not shared by the State, except that the State bears the cost of investigation, plans and reports. The cost is assessed to the railroad companies and the municipality, town or village. The proportion assessable to each of the parties in interest is not fixed by law. It has been the practice of the Railroad Commission of Wisconsin to assess a certain percentage of the total cost of grade separation to each of the parties in interest. This percentage has been varied to conform with changes in conditions found to exist in different cases. Again, the Commission has apportioned the cost of grade separation by outlining the work to be performed by each of the parties in interest. Street and electric railways having locations upon highway crossings which are eliminated are required to bear part of the cost of grade separation."

Wyoming.

PUBLIC SERVICE COMMISSION.

There is no law covering the elimination of grade crossings and no data is available as to any grade crossing elimination work having been done.

District of Columbia.

Grade crossing elimination work in the District of Columbia is governed by Special Acts of Congress. The law covering future work provides that no new streets shall be carried across steam railroad tracks at grade, and in case a street is opened across the right of way, the cost of the part of the viaduct or subway within the railroad right-of-way lines shall be borne equally by the railroad and the Municipality; the cost outside of the right of way to be borne by the Municipality.

In the past the railroads have paid for the work within the right-of-way lines and the Municipality has paid for the part without those lines, except that the cost of changing street railway facilities, gas pipes, electric wires, etc., belonging to public service corporation, has been borne by the owners thereof.

Appendix F.

(7-a) END OR STRAIN POSTS.

T. E. Rust, Chairman, Sub-Committee.

It does not appear that special devices, which have been introduced by the manufacturers of steel posts to avoid the expense attendant upon the use of concrete with strain and corner posts, have been adopted by railroad companies to any extent. But one correspondent reports the use of such devices with tubular posts and, as these were only installed in 1917, their effectiveness has not been determined. The cost of the 8 ft. 6 in. No. 9 gage post in this instance is given at $2.80 and the cost of setting at 40 cents. Two of these devices are shown on Plate I. With that marked "A," a hole is dug for the strain post large enough to admit the anchor plate. After backfilling the hole the face plate is driven. The brace plate is driven after attachment to the brace rod. It is necessary to dig a trench to receive the lower end of the brace rod. The post shown at "B" is driven into the ground as indicated, the post is split at the bottom and is spread out as it nears its final position. This is accomplished by first driving to proper depth a rod having a wedge-shaped enlargement at the lower end greater in diameter than the interior of the post. This arrangement does not work very well in soft ground because the spreader will be forced down with the post.

Some information has been received from the manufacturers concerning a steel line post of U section. These posts are about two inches square. Rectangular steel pegs about 18 in. long are driven through slots in clips bolted on to the posts just below the ground surface to hold the fence in line. Strain and corner posts are tubular, 2½ in. or 3 in. in diameter. A horizontal tubular strut is placed between the strain post and the adjacent line post at about two-thirds the height of the fence and a tie wire or rod leads from the line post end of this strut to the strain post at the ground line. The manufacturers report considerable use of this fence about industrial plants and two railroad companies are also reported to be users. This post is shown at "C," Plate I.

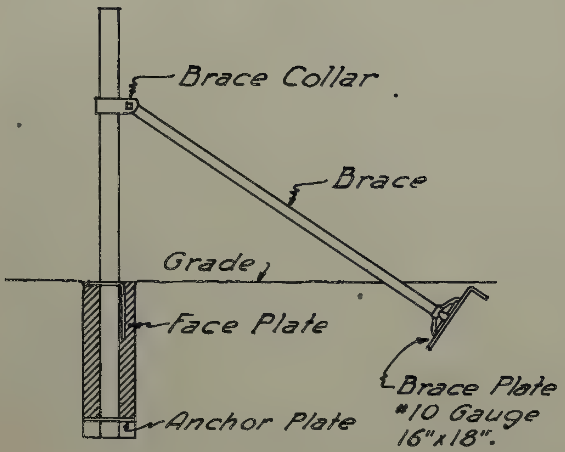
Another form of anchor post is shown on Plate I as "D." This post consists of two standard line posts placed back to back, and either bolted or riveted together, and braced by a standard line post attached to the anchor post as shown by the illustration. This style of post has been used considerably for fences subjected to the lighter service, and has also been used to some extent in railroad right-of-way fences.

Some companies have continued the use of wood strain and corner posts with steel line posts. This has the advantage of cheaper first cost, but its final economy depends, of course, on the relative length of life of the wood post, the steel line post and the wire.

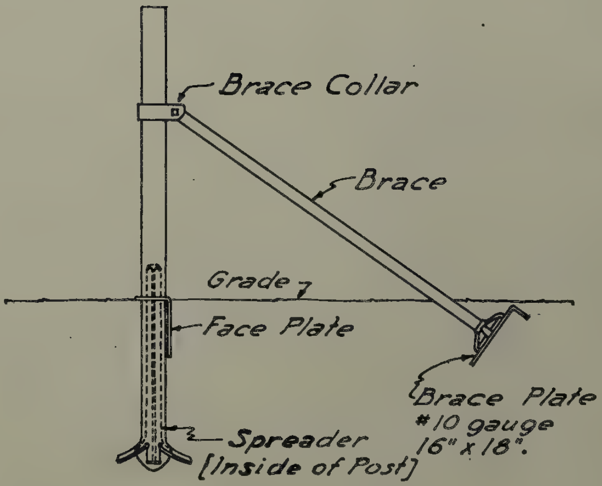
The ordinary method of setting steel strain and corner posts in concrete is well illustrated on Plate II, which shows the standard fence of the Elgin, Joliet & Eastern. There is considerable variation in the amount of concrete used by different companies. Blocks 8 in. square by 36 in. deep are reported by one company, while another uses a block 20 in. square and 42 in. deep. A fair average for such blocks is 18 by 18 by 30 in. Brace rod blocks have about one-half the above volume.

Angular strain posts are provided with a cross angle, similar to a cleat, attached at the bottom by means of a triangular plate. Brace angles, which are attached to the post by means of a bolt or rivet, are similarly enlarged at the bottom. Sufficient information to form an opinion as to the effectiveness of this arrangement has not been received.

Plate I.

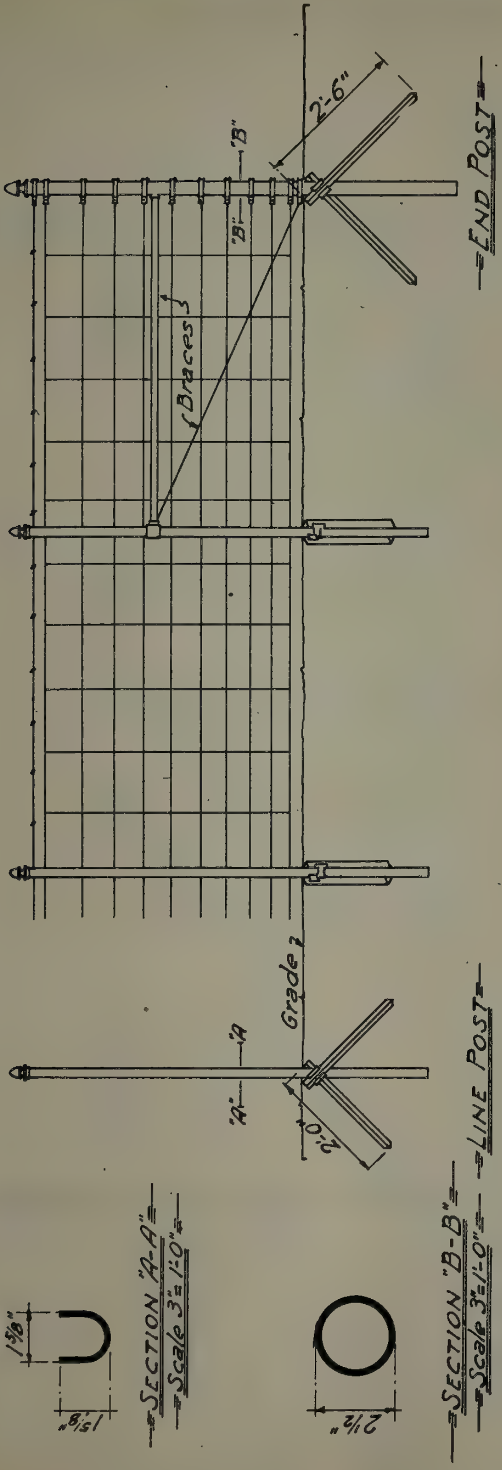


END POST TYPE "A"



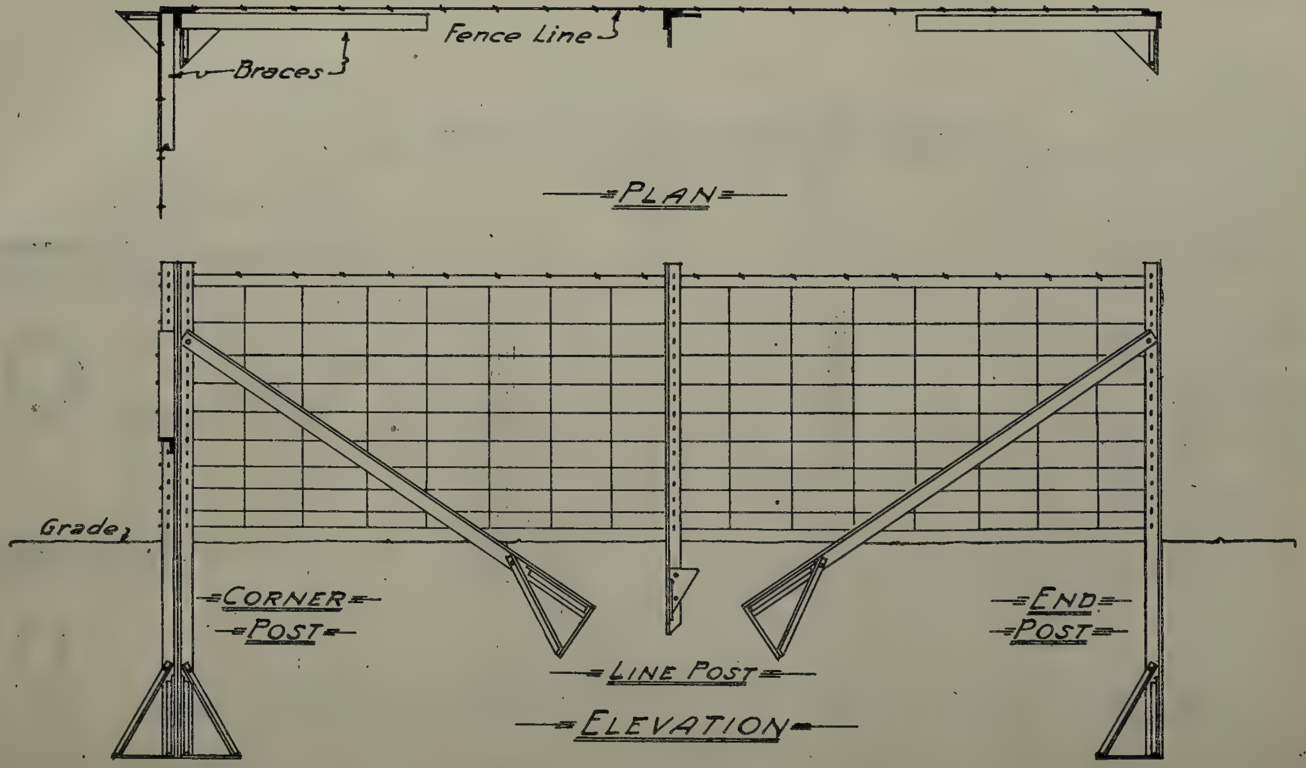
END POST TYPE "B"

Plate I.



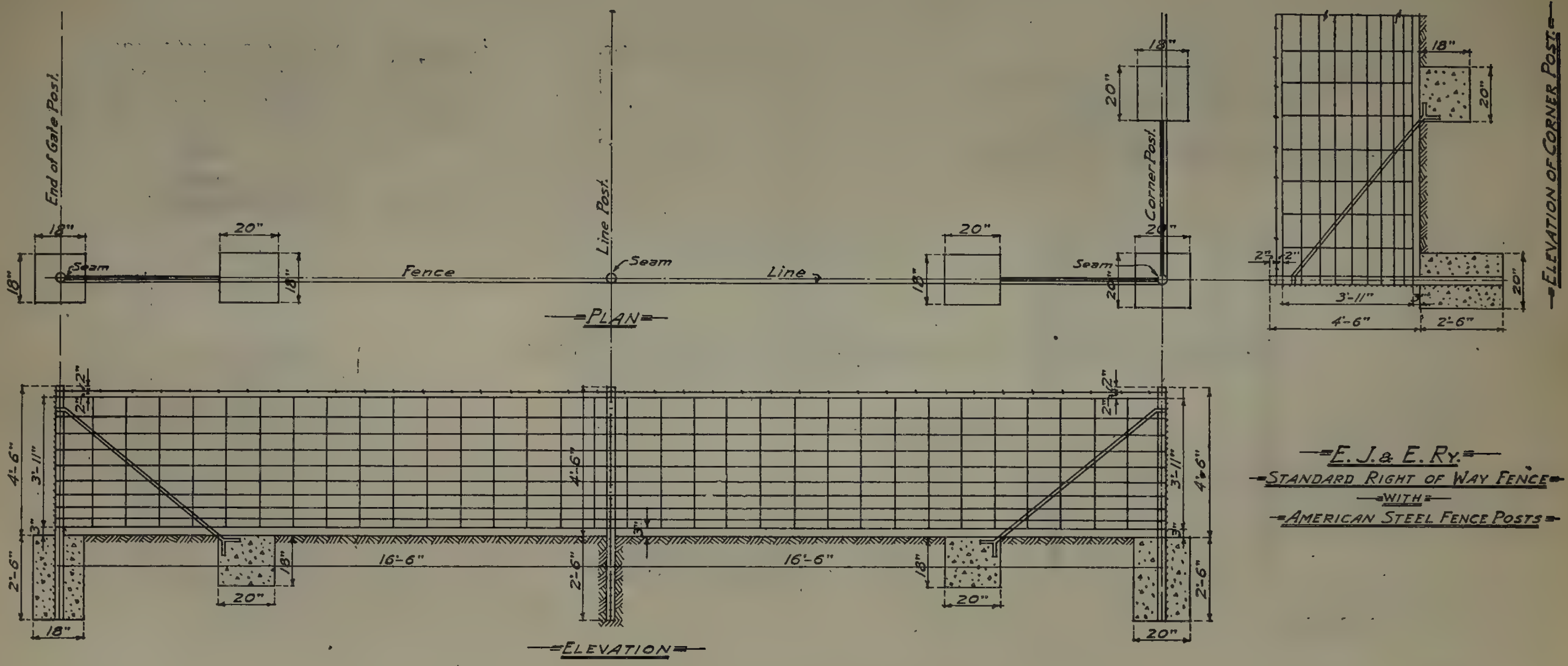
LINE AND END POSTS TYPE "C"

Plate I.



CORNER, LINE AND END POSTS TYPE "D"

Plate II.



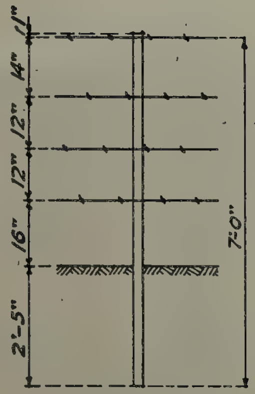
=E. J. & E. Ry.=

=STANDARD RIGHT OF WAY FENCE=

=WITH=

=AMERICAN STEEL FENCE POSTS=

Plate II.

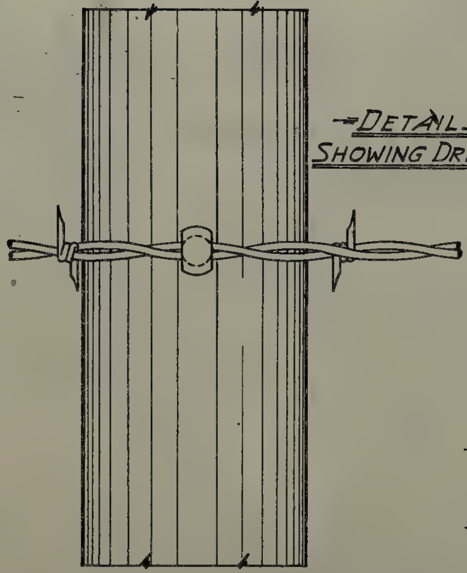


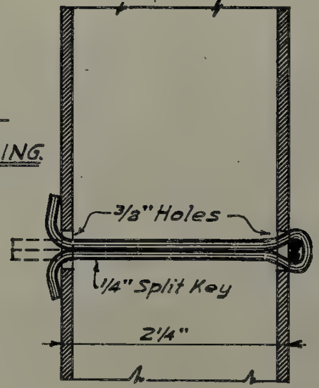
ELEVATION

Scale: 1/2" = 1'-0"

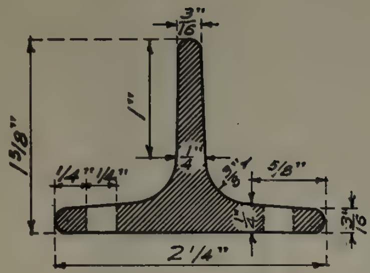
NOTE:-
Tubes to be cut to proper length and drilled in shop as detailed. The entire post to be dipped in hot asphaltum before shipped.

DETAILS
SHOWING DRILLING.

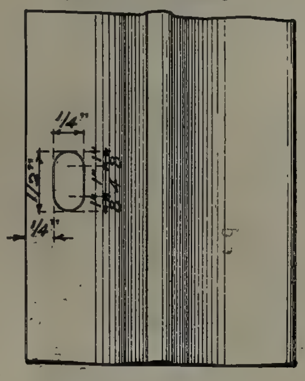




NORTHERN PACIFIC RY.
FENCE POST
MADE FROM OLD BOILER TUBES



SECTION



PLAN

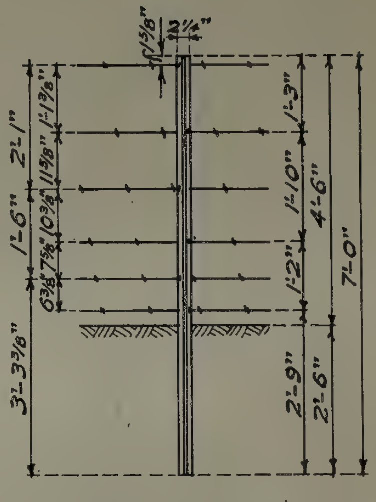
ROCK ISLAND LINES

SECOND DISTRICT COLORADO DIVISION

IRON FENCE POST

IN USE BETWEEN RULETON KANS. AND GENOA COLO.

SINCE 1898



ELEVATION

Total Weight: 19 Lbs.
2.7 Lbs. per Foot.

Appendix G.

(7-c) CONCRETE FENCE POSTS.

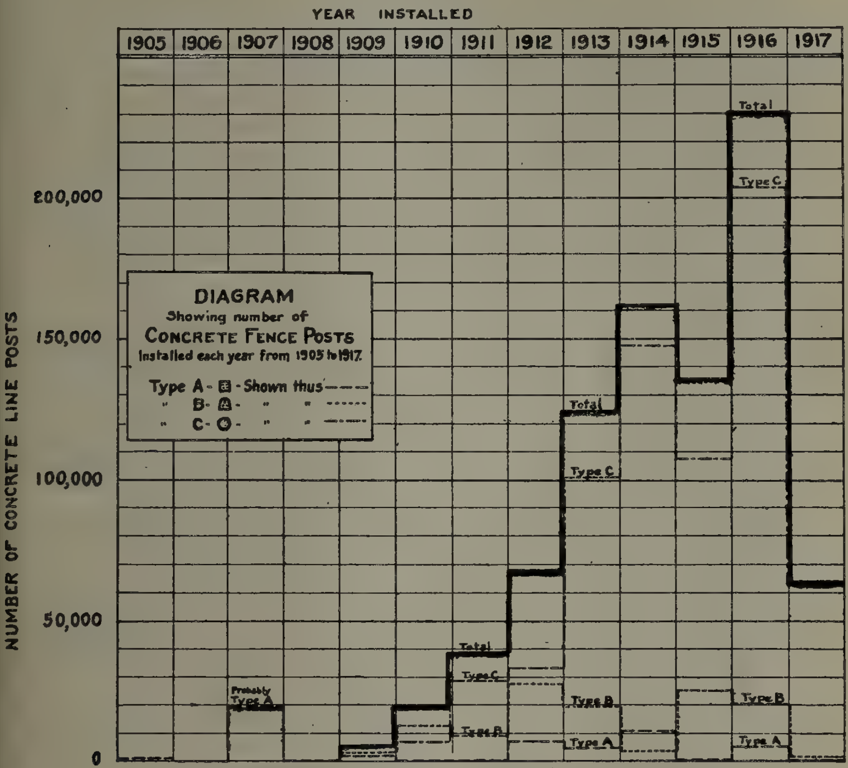
T. E. Rust, Chairman, Sub-Comimttee.

The gradual decrease in the supply of timber and the consequent increase in its cost have naturally turned the attention of Engineers to the question of obtaining a longer life by preservative treatments or of substituting, wherever practicable, some other material for wood. Among the various things for which wood is extensively used by railroads, and for which it would seem that some substitute could be used to advantage, are fence posts. While the Committee does not have any definite data as to the annual expenditure of the railroads for fence posts, it is probable that it is considerably over $1,000,000. There are more than 250,000 miles of railroad lines in the United States and, while this Committee does not know just what percentage of this mileage is fenced, it is quite certain that there are at least seventy-five or one hundred million posts in use, costing on the average 15 cents or more each. This annual expenditure of over $1,000,000 will increase from year to year, and since the cost of wood posts will probably increase faster than the cost of substitutes, it would seem that this Association should continue a systematic study of the cost of and results obtained from these substitutes.

Concrete was first used experimentally in the construction of railroad fence posts some twelve or fourteen years ago, when concrete was hailed as the coming material for many kinds of work. In designing a concrete bridge, building, or other structure subject to stress, Engineers calculate to the best of their ability the magnitude of these stresses and design the structure accordingly; but when the attempt was made to use concrete fence posts, Engineers, to a great extent, seem to have trusted to the designs gotten up by those manufacturing fence post molds. Only a few tests have been made of the strength of various types of concrete posts and little study of the probable stresses to which posts are likely to be subjected.

Apparently the Pennsylvania Railroad began experimenting with concrete fence posts about five years before any of the other roads, the first posts being set by them in 1904. Such good results were obtained with these first posts (see Table "A") that in 1909 they began to experiment on a larger scale. Since 1909 the use of concrete posts by railroads has gradually increased until at the present time there are about 800,000 in service. In a general way, it may be said that these posts are giving good satisfaction, although for various reasons that will be discussed later, a great many failures have occurred and several roads that have experimented quite extensively have abandoned using concrete posts until a more satisfactory design has been gotten out or brought to their attention. The diagram on the following page shows the increased use of concrete posts from 1905 to date.

In addition to the fence posts shown on this diagram, there are doubtless several thousand in use on railroads from which this Committee has been unable to obtain a report. This diagram plainly shows that some railroads are finding concrete fence posts satisfactory and economical, and that the type "C" circular post is far more popular than either the type "A" square post recommended to this Committee in 1915, or the U-shaped, type "B" post.



Note: The 20000 posts placed in 1907 are not shown in Table A

In sending out its inquiries this year the Committee aimed to obtain information regarding the following points:

1. The number of concrete line posts now in use and the type of same.
2. The specifications used by the different roads for line posts.
3. The average cost and life of line posts.
4. The method used for attaching the fence wires.
5. The size, type and cost of strain posts.
6. The methods of bracing strain posts.
7. The preference of the different roads as to concrete, metal or wood posts.

In response to these inquiries the Committee received considerable data from eighteen roads using concrete posts. Sixty-six other roads reported that they had not tried concrete posts or have tried so few that they can give no information of value. In addition to these eighteen roads the Committee knows of several others that have experimented with concrete posts more or less extensively, but from whom it has not been able to obtain any report. Of the eighteen roads that have tried concrete posts, ten favor the use of concrete posts, one favors steel, three favor wood and four are undecided. Of the sixty-six roads that are not using concrete posts, three favor the use of concrete posts, one favors steel, and eight favor wood. The other fifty-four roads did not express a preference. Thus, of the twenty-five roads that did express a preference about 50 per cent. favor concrete posts, 10 per cent. favor steel, and 40 per cent. favor wood.

As a matter of convenience, the Committee this year divided concrete fence posts into five types that were thought to include all the posts now in use by the different roads. These types are shown on the accompanying sketches.

The data regarding concrete line posts is shown in Tables A, B and C; these tables giving the information obtained about types A, B and C line posts, respectively. No road reported the use of type "D" posts, although a few of these triangular posts are thought to be in service. Only one road reported the use of type "E" posts, and as they were installed in 1917, and as the number in use is unknown, it was not thought necessary to tabulate the information.

Table A shows that with two exceptions, none of the square posts in use are as large in cross-section as was recommended by this Committee in 1915 and most of them are much smaller. The costs at the plant ranged from 15½ cents to $1.00, with an average of about 25 cents. Assuming an average cost of 20 cents each to transport and install, the average cost in place would be about 45 cents, and the annual cost of the posts having an average life of fifty years or more would be about 2½ cents. As a post having a square cross-section would seem to be the most economical to resist the stresses to which a post is subjected, it is remarkable that less than 6 per cent. of all the concrete posts in use by railroads are of this shape.

The results obtained with the U-shaped, type "B" post, as shown in Table B, are so diverse that it is difficult to form any conclusions from the data received. Although there is a fair uniformity as to size, reinforcing and mixture, the probable average life and annual cost of the posts made by the different roads seems to be widely different. Apparently, also, the users of this type of post have not kept as close track of the number of post failures as have the roads using other types. It is probable that the average first cost and annual cost of these posts is not much different than those of type "A." The molds in which they are made and patented and the company holding the patents has conducted quite a vigorous advertising campaign, in spite of which only about 15 per cent. of the posts reported in use by railroads are of this type.

The Committee was considerably surprised at the large number of type "C" posts in use. Nearly 700,000 of these posts are now in service, as shown in Table C, and the large number that are being made yearly by the same roads demonstrates that they are being found satisfactory and economical. The average cost of these posts is about 25 cents, the same as for those of type "A," and the average annual cost seems to be about the same. The prominent fact that stands out in this table is the uniformly good results that have been obtained as against the variable results with posts of all other types. This is the more remarkable in that a post of circular section would not seem to be well suited to resist the stresses set up in a fence post as either the square or U-shaped post.

It appears to this Committee that in comparing the merits of the different types of concrete line posts, three things should be considered—strength, resistance to deterioration and first cost—these items being of importance only as they affect the matter of annual cost. Tables A, B and C bring out two things; first, that concrete posts of any of these three types can, by using proper care in their manufacture, be made strong enough to obtain an average life of fifty years or more; and second, that there is not a great deal of difference in the first cost of posts of these different shapes. Assuming, then, that these three types do not differ materially in their resistance to deterioration, it would seem that the best post would be the one which, for a given strength, was the lowest in the first cost. Inasmuch as the posts shown on Tables A, B and C were made under widely different conditions, it would not be proper to use the costs therein shown as an index of the actual relative cost of posts of these three types. It is thought that the best way to make such a comparison is to determine from the available data the minimum strength that a concrete line post should possess and then see which style of post, having that strength, can be the most cheaply made.

It is, of course, very difficult to determine how strong it is economically profitable to make a concrete post, for one reason because the forces that it will have to resist are difficult to determine, and for another because local conditions of climate and soil may make a difference in the strength that will be required. For instance, it is quite probable that posts for use in the South, where the ground never freezes, need not be as strong as those to be used in the colder climates. Fortunately for purposes of comparison, it is not necessary to make this determination with any great degree of accuracy.

If the forces that act on a post could be determined with any precision, they would furnish the best guide as to the minimum allowable strength. Since they cannot, the next best guide is the strength of posts that have been successfully used for a period of years. Most posts break at the ground line, usually when the ground is frozen so that they are held rigidly and act as cantilever beams in resisting whatever stresses may be set up by stock leaning against or striking them, by the malicious or careless mistreatment of trespassers, by the failure of adjacent strain posts, or by other causes. For many years wooden posts averaging 5 in. in diameter, or less, at the ground line have proven amply strong even after being in service through such a period of years that their original strength was very much reduced. Considered as a cantilever beam a red cedar post when new would break under a force of 735 lbs. acting at right angles to its axis and applied 60 in. from the ground line, using 4,800 lbs. per square inch as the ultimate strength of the wood. It seems reasonable to suppose that after six or eight years of service this strength would be reduced so that a load of half that amount so applied would cause failure.

Referring to Table "A," it will be noticed that the only square posts shown that have been in service four years or more are those made by the Missouri Pacific in 1912, by the Pennsylvania in 1904, by the Union Pacific in 1909, and by the Waterloo, Cedar Falls & Northern in 1913. It is impracticable to calculate the strength of the posts made by the Missouri Pacific and the Union Pacific have, apparently, kept no record of failures, so that these posts have not been considered. The size of the reinforcing in the posts made by the Pennsylvania is not known, so that their strength cannot be calculated. Assuming a yield point in the steel of 70,000 lbs. per square inch, the post made for the Waterloo, Cedar Falls & Northern Railway in 1913 would break under a load of about 200 lbs. applied 60 in. above the ground line. The post of this type, as recommended by this Committee in 1914, namely, 5½ in. by 5½ in. at the base by 4 in. by 4 in. at the top would, if reinforced with four 3/16-inch round bars, break under a load of about 260 lbs., if the yield point of the steel were 70,000 lbs. per square inch as above.

Referring to Table "B," it will be noticed that the only posts there shown that indicate an average life of fifty years are those made by the Michigan Central in 1910. The other posts either show a comparatively short life or have not been in service long enough so that any guess as to their life can be hazarded. Assuming as before, a yield point in the steel of 70,000 lbs. per square inch, these posts would break under a load of about 227 lbs. applied 60 in. above the ground line.

As regards the circular posts shown in Table "C," they would withstand a force applied as noted above of from about 160 lbs. for the smaller posts to 235 lbs. for the larger ones.

Considering the good results that have been obtained with posts that would break under loads of from 200 to 235 lbs. applied 60 in. from the ground line, it seems reasonable to conclude that such posts are amply strong and that the failures of posts that would have such a theoretical strength are due to some fault of manufacture. Using posts having the strength to resist a force of 200 lbs., the different types of posts shown on Tables A, B and C might be roughly compared as follows:

Type of Post	Size		Weight in Pounds		Cost of Steel and Cement	
	Top	Bottom	Concrete	Steel	Steel at 4c Pound	Cement at $1.50 Barrel
A	3"x33"	4"x4"	75 lbs.		0.105	0.060
B	3"x 3"	5"x5"	75 lbs.		0.116	0.060
C	3"	5.8"	100 lbs.		0.148	0.080

The type "A" post is considered as being reinforced with four 3/16-inch round rods; the type "B" post with four strips of No. 18 gage hoop steel 5/8-inch wide; the type "C" post with six round rods 11-64-inch in diameter. This latter post is, of course, a purely theoretical one since rods of this diameter and molds of the size given are not used. As regards the types A and B posts there is, of course, little if any choice as to cost, the two shapes being so nearly identical that one is about as efficient as the other. The apparent difference of one cent in cost of reinforcing is really due to the fact that this post is a little stronger than the square post. As to the type "C" post, since the round beam is less efficient than the square one, the difference in size and reinforcing required is not to be wondered at. In case it is assumed that the labor cost of making these different posts is the same, this difference of about five cents in first cost would mean an increase of about three-tenths of a cent in the annual cost. Round posts are easier to handle and placed than square ones, offer better protection to the reinforcing than posts of any other shape, so that their resistance to deterioration should be greater, and, in view of the uniformly good results obtained and the large number in use, this Committee would hesitate to say that this increase of 10 or 12 per cent. in the annual cost is not justified.

Nothing has been said of the type "D" or "E" posts. As to the former, the Committee feels that their triangular shape is not the proper one for efficiency or resistance to deterioration. As to the T-shaped posts, while they would appear to be the most efficient in resisting those forces that would tend to throw the fence side of the post into tension, they are comparatively weak in resisting forces acting in some other direction, as is indicated by the tests made by this Committee in 1914. It also seems that the concrete in the narrow ribs encasing the steel would be easily cracked or chipped off, exposing the steel and thus causing the failure of the post. In burning off the right-of-way it would appear that the narrow ribs would be likely to spawl off from the heat, and in this respect it should be noted that the round post has a decided superiority over all other types. If carefully made, using the best aggregates, this type "E" post may prove satisfactory, but the Committee has no data regarding these posts that will enable them to form any definite conclusion.

This Committee is led to the conclusion, as above stated, that concrete line posts having a strength sufficient to resist a force of 200 lbs. acting along or at right angles to the fence line and applied 60 in. above the ground line, the post acting as a cantilever beam, are strong enough to give good results. Most of the posts shown on Tables A, B and C should, if properly made, be nearly, if not quite as strong, so that the numerous failures are probably due to one of the following reasons:

1. Displacement of reinforcing steel.
2. Improper aggregates.
3. Insufficient cement.
4. Lack of thorough mixing.
5. Too much or too little water used in mixing.

The first cause of failure refers to the reinforcing; the other four to the concrete. Too much stress can hardly be laid on the use of an adequate amount of steel properly placed. In 1914, under the direction of this Committee, seventy-eight concrete line posts of different types were tested to destruction at the Lewis Institute, Chicago. In spite of the fact that the concrete used in the posts varied in its crushing strength from 1,530 to 3,250 lbs. per square inch, every post failed in tension. It is probable that some of the failures were indirectly due to poor concrete allowing the steel to slip, but by far the greater number were due to the failure of the steel itself. Among the other things that were brought out by these tests was that stranded or crimped reinforcing should not be used, but that the steel, whether smooth or deformed, should be in the form of a straight, stiff bar. Referring to the comparatively poor performance of type "A" and "B" posts, this Committee is of the opinion that most of the failures were due to misplacement of the reinforcing steel. It is thought that no uniformly good results will be obtained unless some device is used to secure the reinforcing rigidly in its proper place in the post. The Committee also believes that square or round rods, moderately deformed, are preferable to strap iron, since the former permit the concentration of the steel further from the neutral axis and since the latter tend to set up lines of cleavage in the concrete. Before passing this subject of reinforcing attention is called to the fact that in most posts now in use the amount of steel is insufficient to develop any considerable compressive stress in the concrete. By way of showing the increase of strength obtainable through increasing the size of the reinforcing, consider two concrete posts each 5 in. square at the ground line and acting as cantilever beams with the forces applied 60 in. therefrom, the first post being reinforced with four 3/16-inch round rods and the second with four ¼-inch round rods. Assuming a yield point of 70,000 lbs. per square inch, the first post would break under a load of about 260 lbs., and the second under a load of about 480 lbs. The increased weight of the steel in a 7-ft. post would be about 2 lbs., and the increased cost about eight cents. If the first post cost thirty cents the second would cost thirty-eight cents, so that for a 27 per cent.

increase in cost there would be an 83 per cent. increase in strength. On the other hand, practically doubling the section area and weight of the post without increasing the size of reinforcing would add less than 50 per cent. to its strength and would add eight cents or more to the cost of cement alone, to say nothing of the cost of labor handling and setting.

As to the quality of the concrete used, it need only be good enough to protect the steel and develop its full strength. It would be a very simple matter to make concrete of this quality were it not that the steel is necessarily so close to the surface that a dense concrete is needed for its protection, and for the further reason that slight imperfections that would scarcely affect the strength of concrete in larger masses are disastrous in a slender post. A great many improvements in the making of concrete have taken place in the past few years, so that there ought now to be no excuse for the failure of posts due to any fault of the concrete. One of the most important items in making good concrete is the aggregate. Soft rock or dirty sand or gravel should, of course, be avoided, and a screen analysis made from time to time so that the proper proportions of sand, gravel and stone will be maintained. Any extra trouble on account of screening and remixing will be amply compensated for by the saving in cement and increased strength.

Engineers are just coming to realize that the concrete which, as per the old specifications, has assumed a uniform color may or may not be sufficiently mixed. Mixers may now be equipped with devices that make it necessary to mix the batch a definite length of time before it is dumped, so that the proper length of time required for a thorough mixing may be ascertained and the men running the mixer removed from the temptation of hurrying up the mixing in order to make a good showing for the day's run.

Eight or ten years ago what is now known as dry concrete was very popular. When it was found that this dry concrete was weak and did not properly protect the reinforcing or develop its full strength, many engineers and contractors jumped to the other extreme, so that for several years we had an era of soupy concrete, in which, while the voids were smaller and not as apparent to the eye, they were in fact as great. Only recently has the subject of the proper amount of water been taken up in a serious way and its importance realized. Experiments have been carried on at the Lewis Institute, Chicago, that indicate clearly that the proportion of water has a very large bearing on the strength of the concrete. Fence posts have been made from both the very dry and the very sloppy concrete, and no doubt many failures are due to this cause. It is probable that a definite basis for the proper amount of water to use may be worked out in the next few years, and, in the meantime, Engineers will endeavor to strike a happy medium between the two extremes.

The Committee, in sending out their inquiry blanks this year, asked the members to describe the methods used to fasten the fencing to the line posts and to state what success they were having with such methods. Ten companies are using tie wires around the posts and eight of the ten express themselves as satisfied with this method. Five are using posts with a hole in the same through which a wire or a nail is passed and fastened to the reinforcing. Four of the five are satisfied with this method. Three companies are using staples embedded in the concrete, through which the tie wires or nails are passed for fastening the fencing; this method being satisfactory to all three. When posts are tapered, a tie wire around the post, if properly applied, will prevent stock from crowding the fencing down, but the experience of some roads indicates that it will not prevent hogs from raising it up, so that in districts where hogs are extensively raised some other method of fastening is preferable. It seems to be a simple matter to make a device for placing galvanized loops or staples in their proper place in the post at a small labor cost, and, where tie wires around the posts are not satisfactory, this method would seem to be better than making a hole in the post, which would weaken it to some extent. Another method that might be used is to make grooves or corrugations in the side of the post opposite to the fencing to prevent the tie wires from slipping up or down on the post.

As to the annual cost of concrete line posts, it seems probable that with prices as high as they now are and will doubtless be for several years, the minimum will be about two and a half cents. In the case of materials that have a comparatively short life, such as wooden fence posts, anything that materially increases or decreases the average life will have a considerable effect on the annual cost. For example, if a wooden fence post costing thirty-five cents in place has a life of ten years, its annual cost will be 4.55 cents; whereas, if its life were fifteen years the annual cost would be only 3.22 cents. On the other hand, if concrete line posts costing forty-five cents have an average life of fifty years, the annual cost would be 2.47 cents, and increasing the average life to sixty years would only reduce the annual cost to 2.38 cents. In other words, if we can produce concrete line posts that will have an average life of, say fifty years, we gain very little, as far as annual cost is concerned, by adding a few more years to their life, and any material decrease in this annual cost will have to be effected by reducing the first cost. This brings out the fact that excessively large and expensive concrete posts are to be discouraged and that a post should be built to the size and strength that is economically profitable and no larger.

In line with this idea, it appears to this Committee that any specification as to minimum size and reinforcing of concrete posts is a mistake. In spite of all devices and safeguards the quality of concrete is and will always be largely dependent on the human element and on local conditions, and the Committee believes that such posts should be built to a minimum strength rather than size. Just what this strength should be, the Committee is not prepared to say at this time, but it is quite certain that posts capable of withstanding a load of 200 lbs. when tested as a cantilever beam, in the manner described elsewhere in this report, would be strong enough and it is thought that this strength may be greater than is necessary, particularly in some localities. Some years ago one of our larger railroads tested some of the concrete posts on their line. The information as to just how the test was conducted and how far above the ground line the load was applied is not available, but as line posts rarely project more than 60 in. above the ground in ordinary right-of-way fence, it is probable that the load was applied somewhat less than this distance. The concrete in these posts failed under an average load of 183 lbs., and since the breakages of these posts in service were very large it seems that, in the northern part of the country at any rate, the strength should not be reduced much under that necessary to resist a load of 200 lbs. Of course, it is quite possible, that there was a wide variation in the strength of the individual posts made by this railroad, and that it was not posts of average strength, but those considerably weaker than the average that broke in service.

CONCLUSIONS.

The conclusions of this Committee, based on the information obtained this year, may be summed up as follows:

1. The Committee repeats its conclusion of 1914 that, "Concrete fence posts are practical, economical and a suitable substitute for wood."
2. Reinforcement should be placed as near to the surface of the post as practicable, say ½-inch from the surface.
3. Posts should taper from base to top.
4. Square corners of posts should be rounded off to a radius of not less than 1 inch.
5. Concrete should be made from clean, hard, aggregates, the percentage of the various sized grains being such as to produce a dense concrete, using screen analysis as a guide. The minimum size of the particles of gravel or crushed stone should not be less than ¼-inch nor more than ½-inch. Concrete should be mixed in the proportion of one part cement to not more than four parts of mixed aggregate. Concrete should be of such a consistency that water can be brought to the surface by tamping; the use of an excess of water is detrimental. Concrete should be very thoroughly mixed in a batch, not a continuous mixer.
6. Reinforcing should be in the form of stiff round or square rods, preferably deformed, made from steel with a high elastic limit. Crimped or stranded reinforcing that would be straightened out when brought into tension should not be used. Some method of positively holding the reinforcing in its proper place in the post throughout its entire length should be used.
7. Jogging or vibrating molds to compact the concrete in the post, or some other method that will accomplish the same purpose, should be employed.
8. Posts should be carefully made so as to secure a uniform

strength in substantially all posts, and this strength should usually be such that the post will withstand a force of not less than 180 lbs. at right angles to the axis of the post, the post acting as a cantilever beam supported at the ground line and the force being applied 60 in. above the ground line. It is not economical to make posts that will have the strength to resist a force of over 200 lbs. when the post is tested in the manner above described.

9. Square, or nearly square, posts are more efficient than round posts in resisting the forces that ordinarily cause failure, but the difference is not very great and may in some cases be offset by an increased resistance to deterioration and better methods of manufacture.

10. On account of rapid failure of reinforced concrete when exposed to air containing salt spray, concrete fence posts should not be used within twenty- or twenty-five miles from large bodies of salt water.

11. Posts should not be made out of doors in freezing weather. They should not be exposed to the sun, and should be sprinkled with water the first eight or ten days after being made to aid curing.

12. Molds should be carefully oiled or soaped to prevent concrete sticking to them.

13. Posts should be cured for not less than 90 days, when cured naturally, before being set or shipped.

14. Posts should be carefully handled and packed in straw, sawdust or other suitable material for shipment.

15. The study of the results obtained from concrete line posts should be continued from year to year and the results tabulated for the information of the Association.

Section of Type "A" Post. -

s	Failures to Date					Estimated Average Life	Estimated Annual Cost
al	From lack of strength	From Deterior.	Total	Average per Year	Per cent per year		
	175	840	1015	203	2.9	17 years	2.6¢
	Up to 1909 20	0	20	5	0.8	Over 50 yrs	2.4¢
¢	0	0	0				
5¢	50	0	50	13	0.3	Over 50 years	2.5¢
5¢	58	0	58	19	0.4	" " "	2.5¢
1¢	8	0	8	3	0.1	" " "	2.8¢

Section of Type "B" Post.

s--	Failures to Date					Estimated Average Life	Estimated Annual Cost
al	Lack of Strength	From Deterior	Total	Average per year	Per cent per year		
	"Large"						
	"						
9¢	Few	0					
	0	0	0	0	0	Over 50 years	
	42	138	180	26	1.9	26 years	3.1¢
			"Large"				
			"				
	0	Few					
r. ¢	0	0	0	0	0		

Section of Type "C" Post.

s	Failures to Date					Estimated Average Life	Estimated Annual Cost
tal	From lack of Strength	From Deterior.	Total	Average per Year	Per cent per year		
			3			Over 50 yrs.	
	0	0	0	0	0	" " "	Prob. not over 2.9¢
	0	0	0	0	0	" " "	Prob. not over 2.6¢
	About 6500		6500			" " "	Prob. not over 2.3¢
out 3¢	0	0	0	0	0		
¢ 9¢	About 1200	0	1200			Over 50 yrs.	4.3¢ *

strength in substantially all posts, and this strength should usually be such that the post will withstand a force of not less than 180 lbs. at right angles to the axis of the post, the post acting as a cantilever beam supported at the ground line and the force being applied 60 in. above the ground line. It is not economical to make posts that will have the strength to resist a force of over 200 lbs. when the post is tested in the manner above described.

9. Square, or nearly square, posts are more efficient than round posts in resisting the forces that ordinarily cause failure, but the difference is not very great and may in some cases be offset by an increased resistance to deterioration and better methods of manufacture.

10. On account of rapid failure of reinforced concrete when exposed to air containing salt spray, concrete fence posts should not be used within twenty- or twenty-five miles from large bodies of salt water.

11. Posts should not be made out of doors in freezing weather. They should not be exposed to the sun, and should be sprinkled with water the first eight or ten days after being made to aid curing.

12. Molds should be carefully oiled or soaped to prevent concrete sticking to them.

13. Posts should be cured for not less than 90 days, when cured naturally, before being set or shipped.

14. Posts should be carefully handled and packed in straw, sawdust or other suitable material for shipment.

15. The study of the results obtained from concrete line posts should be continued from year to year and the results tabulated for the information of the Association.

TABLE A

Concrete Fence Posts ~ Type "A"

Section of Type "A" Post.

Company Reporting	Approximate Number of Line Posts	Year Placed	Made by Company or Purchased	Dimensions			Mixture by volume				Mixed Wet or Dry	Reinforcing	Molds		Spacing of Line Posts		Approximate Cost of Line Posts					Failures to Date					Estimated Average Life	Estimated Annual Cost
				Top	Bottom	Length	Cem.	Rock	Sand	Grav.			Wood or Steel	Station. or Jogging	Tangent	Curve	At Plant	Freight to Mat'l Yard	Work Train	To Set	Total	From lack of strength	From Deterior.	Total	Average per Year	Per cent per year		
Long Island	2000	1916	Company	4½"×6"	6"×6"	8'-0"	1		4	3	Wet	Four ¼" twisted	Wood	Station	20'	Var.	42¢											
Missouri Pacific	7000	1912	Purchased	3"×3"	3"×3"	7'-0"	1		1	3	"	#20gage sheet, X shaped	Steel	"	20'	20'	15½¢	1½¢				175	840	1015	203	2.9	17 years	2.6¢
P.R.R., Lines W., N.W. Syst.	638	1904-5	Company	2½"×2½"	4½"×4½"	8'-0"						Four wires					22.7¢					Up to 1909 20	0	20	5	0.8	Over 50 yrs	2.4¢
St. Louis & San Francisco	12	1916	"	4"×4"	6"×6"	7'-0"	1		2	4	Wet	Four ¼" sq. bars	Wood	Station.	12'		$1.00			15¢								
Southern	2800	1916	"	4"×4"	5½"×5½"	8'-0"	1	2	4		"	Four No.7 wires	"	"	16½'	16½'	Aver 30¢		Aver. 4¢	10¢	44¢	0	0	0				
W.C.F. & N.	4528	1913	Purchased	3"×3"	4"×4"	6'-6" 7'-0"	1			3½	Med.	Four 3/16" round, crimped	"	"	20'	16½'	25¢	0	Not over 5¢	15¢	45¢	50	0	50	13	0.3	Over 50 years	2.5¢
" " " " "	5500	1914	"	3"×3"	4"×4"	6'-6" 7'-0"	1			3½	"	" " " "	"	"	20'	16½'	25¢	0	5¢	15¢	45¢	58	0	58	19	0.4	" " "	2.5¢
" " " " "	5300	1914	"	3"×3"	4"×5"	7'-0"	1			3½	Wet	Four ¼" round, deformed	Steel	Jogging	20'	16½'	31¢	0	5¢	15¢	51¢	8	0	8	3	0.1	" " "	2.8¢
Union Pacific	About 2000	1909	"	3½"×3½"	3½"×4½"	6'-8"	1		4			#24 gage sheet core & four #8 wires	"		Var.		35¢	0										

TABLE B

Concrete Fence Posts ~ Type "B"

Section of Type "B" Post.

Company Reporting	Approximate Number of Line Posts	Year Placed	Made by Company or Purchased	Dimensions			Mixture by volume				Mixed Wet or Dry	Reinforcing	Molds		Spacing of Line Posts		Approximate Cost of Line Posts					Failures to Date					Estimated Average Life	Estimated Annual Cost
				Top	Bottom	Length	Cem.	Rock	Sand	Grav.			Wood or Steel	Station. or Jogging	Tangent	Curve	At Plant	Freight to Mat'l. Yard	Work Train	To Set	Total	Lack of Strength	From Deterior	Total	Average per year	Per cent per year		
Chicago & North Wn.	2100	1914-15	Company	4"×4"	5"×5"	7'-0"					Dry	Three #18 flat, ⅝" wide	Steel	Jogging	16'	16'						"Large"						
" " " "	5000		"	3½"×3½"	5½"×5½"							" " " " "	"	"								"						
Louisville & Nashville	5389	1916	"	3½"×3½"	5½"×5½"	8'-0"	1	4	2		Wet	Various	"	"	20'	20'	29¢	0		40¢	69¢	Few	0					
Michigan Central	1000	1910	Purchased	3"×3"	5"×5"	8'-0"	1			4	"	Four #18 flat, ⅝" wide	"	"	16½'	16½'						0	0	0	0	0	Over 50 years	
Missouri Pacific	1382	1910	Company	3"×3"	5"×5"	7'-0"	1		2	4	"	" " " " "	"	"	20'	20'	23¢	0				42	138	180	26	1.9	26 years	3.1¢
P.R.R., Lines W., N.W. Syst.	45253	1909-13	"	3"×3"	5"×5"	7'-6"	1			4	"	Three " " " "	"	"			20¢							"Large"				
" " " " " S.W. "	24562	Prior to 1914	"	3"×3"	5"×5"	7'-6" 8'-0"					"	" " " " "	"	"	Max. 24'		19¢							"				
Twin City Rapid Transit	3000	1915-17	"	3"×3"	5"×5"	7'-0"	1			2	"	Three ⅛"×1" flat	"	"	16'	16'	40¢					0	Few					
Del., Lackawanna & Wn	37754	1915-17	"	3"×3" 3½"×3½"	5"×5" 5½"×5½"	7'-6"	1		2	4	"	One #1 & two #3 rods	"	"	10'	10'	18¢ to 24¢	0	About 3¢	About 8¢	Aver. 31¢	0	0	0	0	0		

TABLE C

Concrete Fence Posts ~ Type "C"

Section of Type "C" Post.

Company Reporting	Approximate Number of Line Posts	Year Placed	Made by Company or Purchased	Dimensions			Mixture by volume				Mixed Wet or Dry	Reinforcing	Molds		Spacing of Line Posts		Approximate Cost of Line Posts					Failures to Date					Estimated Average Life	Estimated Annual Cost
				Diameter		Length																						
				Top	Bottom		Cem.	Rock	Sand	Grav.			Wood or Steel	Station or Jogging	Tangent	Curve	At Plant	Freight to Mat'l. Yard	Work Train	To Set	Total	From lack of Strength	From Deterior.	Total	Average per Year	Per cent per year		
Chicago, Burlington & Quincy	213361	1913-17	Company	3½"	4½"	7'-0"	1		3		Wet	Six No. 9 wires	Steel	Jogging	32'	32'								3			Over 50 yrs.	
Chicago, Rock Island & Pacific	15288	1913	"	4"	5½"	7'-0"	1			3¼	"	" " 8 "	"	"	20'	20'	31.8¢					0	0	0	0	0	" " "	Prob. not over 2.9¢
" " " " "	22062	1913	"	3½"	5"	7'-0"	1			3¼	"	" " " "	"	"	20'	20'	27.5¢					0	0	0	0	0	" " "	Prob. not over 2.6¢
Cleve., Cincin., Chicago & St. L.	204331	1910-17	"	3½"	5"	7'-0"	1			3	"	" " 9 "	"	"	20'	20'	21.3¢					About 6500		6500			" " "	Prob. not over 2.3¢
Illinois Central	116000	1916	"	4"	5½"	7'-0"	1		2	4	Dry	" " " "	"	"	16½'	16½'	28¢		4¢	10¢	About 43¢	0	0	0	0	0		
New York Central	40603	1911-17	"	3½"&4"	5"&5½"	7'-0" 8'-0"					Wet	6 No. 8 wires and 4 No. 14 wires	"		20'	16½'	Aver 0.30		9¢	40¢	79¢*	About 1200	0	1200			Over 50 yrs.	4.3¢*

* This probably an error since cost of setting should not be over 20¢

Appendix H.

(8) ANALYSIS OF COST.

T. E. Rust, Chairman, Sub-Committee.

For the purpose of making a revised analysis of the comparative annual cost of fences, inquiries were sent out soliciting data on concrete and steel line posts only, the intention being to use the data collected in 1915 for wood posts. In 1913, information was submitted with respect to the comparative cost and economy of steel and wood posts. The figures relative to steel posts given at that time were furnished largely by the manufacturers. This year information has been received from twenty users of about 140,000 steel posts and eighteen users of about 800,000 concrete posts, and a comparison has been made between this and the rather full information relating to wood line posts, presented in 1915.

From 1915 data it appears that the average cost and life of wood posts is as follows:

Kind of Wood	*Life*	*First Cost*	*Handling*	*Setting*	*Total Cost*
Bois D'arc	26 Yrs.	14c	1.72	8.52	24¼c
Catalpa	12 Yrs.	17c	1.72	8.52	27¼c
Cedar	15 Yrs.	16c	1.72	8.52	26¼c
Chestnut	11 Yrs.	14c	1.72	8.52	24¼c
Cypress	11 Yrs.	20c	1.72	8.52	30¼c
Locust	17 Yrs.	20.5c	1.72	8.52	30¾c
Oak	9 Yrs.	14.5c	1.72	8.52	24¾c
Pine	8 Yrs.	11c	1.72	8.52	21¼c

Of the above the cedar post is the cheapest, with the exception of the Bois D'arc, and is used in much larger quantities than any of the others. The steel and concrete posts will be compared with it. Information received this year indicates the average first cost of the steel line post to be 27 cents and the cost of handling and setting, 7 cents. The average estimate of life is from fifteen to twenty years. The average first cost of concrete line posts is about 25 cents, and the cost of handling and setting about 20 cents. The estimated life of concrete posts is placed at fifty years.

As in the 1913 report, interest is assumed at 6 per cent. The result of this comparison is as follows:

	Wood	*Steel*	*Concrete*
Estimated average life	15 yrs.	20 yrs.	50 yrs.
Average first cost in place	0.2625	0.340	0.4500
Annual Cost			
Interest on first cost at 6 per cent.	0.0157	0.0204	0.0270
Amount to be set aside annually to reproduce first cost at end of life	0.0113	0.0092	0.0015
Total annual cost	0.0270	0.0296	0.0285
Cost per mile (640 posts)	17.28	18.97	18.24

The above comparison should be considered as roughly approximate only, when applied to a particular case, because the life of wood, steel and concrete posts is affected by locality and the weight of metal and quality of galvanizing must be taken into account. At the present time steel posts are from 50 per cent. to 75 per cent. higher in price than quoted above, and deliveries are very indefinite.

The information received relative to the cost of strain and corner posts in place is so meager and variable that a comparison similar to the above for line posts does not seem warranted.

REPORT OF COMMITTEE II—ON BALLAST.

H. E. Hale, *Chairman;*
C. W. Baldridge,
J. S. Bassett,
W. J. Bergen,
H. E. Boardman,
C. J. Coon,
T. W. Fatherson,
G. H. Harris,
F. A. Jones,
J. S. McBride,
William McNab,
F. J. Parrish,
J. M. Meade, *Vice-Chairman;*
S. B. Rice,
H. L. Ripley,
H. E. Stansbury,
Paul Sterling,
F. J. Stimson,
D. W. Thrower,
W. Trapnell,
D. L. Sommerville,
W. K. Walker,
R. C. White,
W. D. Williams,

Committee.

To the American Railway Engineering Association:

The Committee on Ballast submits herewith its annual report for 1918.

The subjects which were assigned to the Committee by the Board of Direction are as follows:

Subjects Assigned to Sub-Committee No. 1.

(a) Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

(b) Report on the proper depth of ballast of various kinds to insure uniform distribution of loads on the roadway, conferring with Special Committee on Stresses in Railroad Track and Committee on Roadway.

Sub-Committee No. 1.—J. M. Meade, Chairman; C. W. Baldridge, H. E. Stansbury, F. J. Stimson, D. W. Thrower, W. Trapnell.

The report on these two topics is given in Appendix A.

Subjects Assigned to Sub-Committee No. 2.

Report on methods and cost of applying ballast, with special reference to the following plans:

(a) Organization of the most economical ballast gang of railway company forces.

(b) Use and limitations of mechanical tools, such as the pneumatic tamper and the spreader for forming shoulder and path.

(c) Application by contract.

Sub-Committee No. 2.—H. L. Ripley, Chairman; T. W. Fatherson, G. H. Harris, William McNab, S. B. Rice, Paul Sterling.

Report on this subject appears in Appendix B.

Subjects Assigned to Sub-Committee No. 3.

(a) Report on the comparative merit of different stones and gravel and other material for ballast.

(b) Report on the different kinds of physical tests of ballast (chemical also, if necessary), and the manner of conducting them, and recommend the tests which are considered necessary and sufficient to form a guide for comparing the suitability of various stones and other material for ballast.

Sub-Committee No. 3.—C. J. Coon, Chairman; W. J. Bergen, H. E. Boardman, F. J. Parrish, D. L. Sommerville, W. D. Williams.

The report on these two subjects appears in Appendix C.

Subjects Assigned to Sub-Committee No. 4.

Report on ballast sections, with particular reference to sub- and top-ballast.

Sub-Committee No. 4.—R. C. White, Chairman; J. S. Bassett, F. A. Jones, J. S. McBride, W. K. Walker.

A report on this subject is given in Appendix D.

COMMITTEE MEETINGS.

Two meetings of the General Committee were held during the year, the first in Chicago on June 18, 1917, with eleven members present, the second in New York on November 23, 1917, with eight members present. Various Sub-Committee meetings were held.

MISCELLANEOUS.

As a matter of interest, the Committee presents, in Appendix E, "Specifications for Stone Ballast" of the Pennsylvania Lines West of Pittsburgh.

CONCLUSIONS.

Your Committee on Ballast recommends the following action be taken on its report:

1. That the changes in the Manual, under the heading of "Revision of Manual," in Appendix A, be approved.
2. That the additional definitions given in Appendix A be approved and published in the Manual.
3. That the phraseology given in Appendix C, in regard to "Physical Tests of Ballast," be approved for the Manual.
4. That the ballast sections shown in Appendix D be approved and published in the Manual.

Respectfully submitted,

The Committee on Ballast.

Appendix A.

(1) (a) REVISION OF MANUAL.

J. M. MEADE, Chairman, Sub-Committee.

Under the heading "Depth of Ballast" in the Supplement to the Manual as published in Bulletin No. 197, Vol. 19, insert the word "proper" after the first word "the," making the paragraph read, "The *proper* depth of ballast under the tie," etc.

ADDITIONAL DEFINITIONS.

SKELETONIZING TRACK.—The digging out and removal of all material from over and between the ties down to a level with or below the bottom of the ties.

SHELL BALLAST.—A ballast composed of marine shells of all kinds which are washed into heaps in the shallow water along the Gulf Coast. These shells, for use as ballast, mixed with small per cent. of sand, are secured by dredging.

GRANULATED SLAG.—Granulated slag is the product of the blast furnace, formed by having a jet of water injected into the molten slag as it runs from the furnace. This treatment reduces the slag to a granular form.

BLAST FURNACE SLAG.—Slag from blast furnaces, which is poured out as molten slag and allowed to cool. It is then broken up by blasting or otherwise, for use as ballast. This type of slag is of a light gray color, is quite porous and lighter in weight than majority of stone ballast.

OPEN-HEARTH SLAG.—Open-hearth slag is a product of the open-hearth steel furnaces, is very black and dense, and contains a considerable quantity of iron, is quite heavy, and breaks in angular form, and therefore makes excellent ballast.

PRECIOUS METAL SLAG.—A slag from smelters for reducing precious metals; is very similar in appearance and consistency to the open-hearth slag. The precious meal slag is usually black or very dark in color, is very hard and heavy, and, when properly crushed, makes an excellent ballast.

VOLCANIC CINDERS.—Volcanic cinders are the cinders thrown out by volcanic eruptions and deposited in hills and mountains, partially free from lava. In appearance, they are much like "burnt clay" or "gumbo" ballast, but are usually darker in color, and much harder and more durable.

(2) REPORT ON PROPER DEPTH OF BALLAST OF VARIOUS KINDS TO INSURE UNIFORM DISTRIBUTION OF LOADS ON THE ROADWAY, CONFERRING WITH SPECIAL COMMITTEE ON STRESSES IN RAILROAD TRACK AND COMMITTEE ON ROADWAY.

(b) Depth of Ballast.

Your Committee has been in touch with the Committee on Stresses in Railroad Track, but as that Committee has not yet completed its investigations of stresses, the Ballast Committee is not in a position to recommend any additions or changes to the matter in the Manual, page 5, under the heading of "Proper Depth of Ballast." The Committee therefore recommends that this subject be reassigned for the coming year's work.

Appendix B.

(4) METHODS AND COST OF APPLYING BALLAST.

H. L. Ripley, Chairman, Sub-Committee.

In connection with sections (a) and (b), the carriers having representation through membership in the Association were circularized and requested by the Secretary to answer the following letter:

> Will you kindly communicate to the address given below, within the next 20 days, information relative to the following subjects?
>
> (1) Mechanical Tools—such as Mechanical Tampers; Spreaders for forming shoulder and path, etc.
>   (a) A list of such tools (other than the common hand tools)—such as Pneumatic Tampers; Electric Tampers; Ballast Plows; Ballast Spreaders; hand and power controlled; other automatic or semi-automatic devices.
>   (b) The results obtained by the use of the Mechanical Tamper (noting the kind) on:
>   (1) Outlying section maintenance.
>   (2) Terminal section maintenance.
>   (3) Around frogs, switches, slips, interlocking, etc.
>   (4) In renewal of ballast out of face.
>   (5) In new construction work.
>   Comment upon the advantages and disadvantages of each for the various classes of ballast work.
>   (c) The results obtained by the use of other mechanical devices, with comments, as in the case of the Mechanical Tamper.
>
> (2) Outline a Typical Ballast Gang.
>   (a) The best typical gang for handling ballast in connection with ordinary maintenance work.
>   (b) The best typical gang to ballast a newly constructed line.
>   (c) The best typical gang to raise out of face and rock-ballast under traffic a line previously ballasted with some inferior material.
>
> Main heading, (2) "Outline a Typical Ballast Gang," should, preferably, be accompanied by a diagram or diagrams showing the organization split into its various sub-units, with the class and number of Foremen, Sub-Foremen, and men in each gang, indicating the spacing in the gang and distances between sub-gangs.
>
> Please state in particular whether tie renewals are made before, at the time of, or subsequent to ballasting, and why.
>
> In each case copious comments in narrative form should accompany the outline, the narrative to show the exact duties of each sub-gang. It should be in sufficient detail to enable one unfamiliar with the conditions to classify properly and summarize the results obtained.
>
> Information relative to the amount of work accomplished, and cost, would be welcomed by the Committee.

Owing, doubtless, to the unusual stress under which railroad officers have been compelled to work in recent months, only sixteen (16) replies were received. Of this number, eight (8) confined themselves to an answer relative to tampers, plows and spreaders; eight (8) replied by outlining a typical ballast gang as well. No diagrams were submitted.

Of the eight (8) replies to question regarding the ballast gang, five (5) advocate a large gang of 50 men or over. Three (3) advocate a small gang of 30 men or less, with independent gangs to speed up the work when necessary.

The organization suggested by the Committee is based upon the assumption that the material will be dropped from center dump cars and will be dragged down, and further, that on an old line a skeletonizing gang will do the preliminary work, in advance of and distinct from the ballast gang.

For such a typical ballast gang your Committee suggests a slight modification of the one shown by diagram on page 464 of the Proceedings for 1917, Volume 18, and has indicated this modified form as Exhibit "A."

> Committee's Exhibit "A." (See addenda): 55 Men, 1 Clerk, 4 Sub-Foremen, 1 General Foreman.
>
> The New York Central Diagram shown on page 464 of the Proceedings for 1917 (Exhibit "B") consists of: 53 Men, 2 Sub-Foremen, 1 General Foreman.
>
> The Michigan Central Diagram shown as Exhibit "C" consists of: 102 Men, 2 Sub-Foremen, 2 General Foremen, 1 Tool Man, 1 Water Boy, 1 Company Inspector.
>
> The Grand Trunk Railway System Outline is shown as Exhibit "D" and consists of: 49 Men, 2 Sub-Foremen, 2 Foremen.
>
> The Oregon Short Line Outline shown as Exhibit "E" consists of: 54 Men, 2 Sub-Foremen, 1 Foreman.
>
> The Richmond, Fredericksburg & Potomac Outline shown as Exhibit "F" consists of: 48 Men, 1 Clerk, 3 Sub-Foremen, 1 Foreman.

The above gang (Committee Exhibit "A"), as before stated, is designed for ballasting a line after a preliminary skeletonizing and tie gang has prepared the way.

Before ballasting an operated line, such an advance gang would be required to clean out the spent ballast to the bottom of the tie; to lower track under overhead obstructions; to clean ditches and slopes; to load out the excavated material required for proper width of roadbed. This advance gang would consist of from 12 men and sub-foremen, to 50 or more men, a foreman and two or three sub-foremen working with ditcher and train, depending on the magnitude of the preparatory work required by local conditions.

A typical tie-renewal gang would consist of a sub-foreman and 16 men and should follow the advance gang on old track. This typical gang would consist of:

1	Sub-Foreman
2	Clawbar Men
4	Removing Old Ties
6	Placing New Ties
2	Lifting-Bar or Jack Men
2	Spikers.

Other than the necessity for preparatory work as indicated above, your Committee sees no reason for any different organization to handle ballast on a new line and on an operated line. At the time the ballasting would be under way on a new line, work trains would be in use and the line might be carrying as frequent service as would a lightly operated line in commercial service. It would have to be kept passable in either case.

If little service other than the ballast train had to be taken care of, it would be an advantage to spread out the gang somewhat more than is indicated on Exhibit "A." If service was frequent, the gaps would have to be narrowed and more attention paid to keeping the track supported in order to prevent surface bending the rail.

CONCLUSION.

The data furnished the Committee has been meager and the study made is not conclusive. The diagram submitted by the Committee is nothing more than a good target at which to shoot during the coming year.

It is submitted for that purpose in the hope that each member of the Association will not only take his shot at it but will send to the Chairman a design for a new and better target so that the Committee may next year submit one to the meeting that reflects the combined experience and judgment of the Association together with a summary of the constructive criticism presented by representatives of all the affiliated carriers.

The Committee recommends that the letter of inquiry be followed up until such answers are secured.

(b) USE AND LIMITATION OF MECHANICAL TOOLS.

Mechanical devices used to save labor and expense and to expedite the work fall naturally into sequence from the pit, quarry or ballast pile to the finished track.

Your Committee assumes that the Association did not expect it to cover hand tool nor jacks nor to cover the machinery employed in preparing and loading ballast. That is a study in itself.

Cars for transporting ballast should be carefully chosen with regard to the work to be done—whether it is to be on track already laid or for an additional parallel track.

If for raising track hopper cars should be used with the ballast plow or tie drag. If for parallel track side dumps are to be preferred, especially when air operated. Convertible cars where the sides swing out and up, when used with the side plow and unloading engine-drum and cable, are fairly satisfactory when dump cars are not available, which is usually the case when stone ballast is furnished from a private quarry.

Anchoring the train and pulling the plow through the train by cable from the locomotive is a poor substitute for the unloading engine. It does beat unloading by hand.

The spreader car, especially when air-operated, is effective and should be in general use. With this car, ballast for new second track work previously dumped alongside the running track from side dump cars or unloaded by side plows, can be spread out to a grade two inches below the bottom of tie and to the outside shoulder at a speed of eight miles per hour. When not in use on ballast work the spreader can be used on a grading dump and in wet clay or rock will do the work of fifty men and remain idle most of the time at that.

The only other mechanical tool, as your Committee understands the term, which seems to require particular mention, is the mechanical tamper.

This tool has passed the stage where its usefulness under favorable circumstances needs further defense.

Around terminals and yards where there is a large amount of frog and switch work, so far as this Committee knows there is no disposition to question the expediency of its use based on its merits alone, entirely apart from any question of scarcity of labor.

Opinions differ as to the amount of labor the mechanical tamper will save. It is probably conservative to say that a gang consisting of one (1) foreman and twelve (12) men, with four (4) pneumatic tampers can do as much work in a day as twenty (20) men with picks or tamping bar, and do it better. Some supervisors set the figure much higher in congested territory.

An outline of a typical four-unit and two-unit gang follows:

MAINTENANCE GANG FOR PNEUMATIC TAMPER.

Four-Machine Outfit.	Two-Machine Outfit
Foreman:	Foreman:
1 Compressor Runner	1 Compressor Runner
2 Hose and Utility Men	1 Hose and Utility Man
4 Tampers	2 Tampers
4 Shovel and Bar Men	2 Shovel and Bar Men.
1 Lookout.	

In either case on maintenance work it is assumed that the whole crew working as a unit would renew ties, clean out for tamping and do other preliminary work in advance of the machines.

It should be borne in mind, however, that the outfit required with mechanical tampers is complicated and will break down if not properly handled.

It is a gas engine and is susceptible to all the potential troubles that go with an automobile, substituting hose troubles for tire troubles.

It is an air compressor and requires the same care and is susceptible to the same troubles as any other compressor.

The tamping tool is much like a "Jap" Drill and has its own peculiar troubles.

When used at a terminal when the apparatus can receive proper attention from a mechanic, these troubles are not serious. When sent out on a section and left to the tender mercies of the average foreman of an outlying section gang, unless regularly inspected and "tuned up" by someone having the necessary mechanical knowledge not only to put the outfit in shape but to instruct the foreman in its use, it is liable to be out of order, and out of service a considerable portion of the time.

Cost figures were published in the Proceedings for 1916, Volume 17, page 325.

Some additional cost figures follow:

N. Y. N. H. & H. R. R.

RECORD OF TIE TAMPING MACHINES.

Two (2) Tamper Outfit.

1 Foreman—6 Men. November 14, 1917.

Hours Operated.	Number of Ties Tamped.	Linear Feet of Track.	Ballast.	Cost Per Tie, Labor and Supplies, Including Lost Time.	Remarks.
45 out of 60	1380	2267	Stone	$0.103	All ties tamped
14 " " 40	555	902	"	0.141	" " "
26 " " 50	485	1200	Gravel	0.158	Picking up low spots
33 " " 60	655	1820	"	0.163	" " " "
35 " " 60	660	2050	"	0.192	" " " "
39 " " 60	765	2650	"	0.155	" " " "
16 " " 30	363	1045	"	0.161	" " " "

All these machines used upon outlying sections upon regular section maintenance. A great deal of trouble experienced on account of air compressor and gasoline engine getting out of order, probably due to inexperienced men handling such outfits. This has resulted in considerable lost time which brings up the unit cost of ties tamped. A battery of three or four machines all under one competent mechanic has proved more satisfactory, unit cost per tie tamped being about $0.05.

ILLINOIS CENTRAL RAILROAD.

ONE AIR TAMPER IN ROCK BALLAST.

Result of general surfacing; raising two inches in order to clean ballast face and renew ties.

Section foremen and 12 laborers. 10 hours per day averaged 234 feet of track. Same gang without machine 180 feet. Cost of former 13½c per foot. Latter 14.6c per foot. Making 1.1c per foot in favor of the machine.

(c) BALLASTING BY CONTRACT.

The carriers were circularized about ballasting by contract and were asked to give the Committee their views in regard to the practicability and the desirability of contracting for the application of ballast:

(a) On new Construction,

(b) On an Operated Line,

first stating whether they had or had not handled ballast work by contract in recent years under either or both of the two classes.

One hundred and seven (107) replies were received in connection with new work. Of this number eighteen (18) replied that they had within recent years handled ballast work by contract on New Construction; nine (9) were in favor of continuing such method of procedure: six (6) were non-committal; three (3) were opposed.

Of the eighty-six (86) who had not within recent years handled ballast by contract on new work, thirteen (13) were in favor of trying such method; thirty-six (36) were non-committal; thirty-seven (37) were opposed.

One hundred and three (103) replies were received in connection with contract ballasting on an operated line.

Of the six (6) who have within recent years handled ballast by contract on operated lines, two (2) were in favor of continuing such practice; three (3) were in doubt, and one (1) opposed. Of the eighty-seven (87) who have not within recent years handled ballast by contract on an operated line, eight (8) were in favor of trying such procedure; thirty-two (32) were non-committal; fifty-seven (57 were opposed.

On new lines the arguments in favor of contract work as brought out by the replies were two:

1. Flexibility of supply and control over labor owing to freedom in fixing rates of pay.
2. A possible low price owing to some local condition, such as lack of proper equipment on the part of the carrier.

The disadvantages were:

(a) Loss of control over the work.
(b) Less thorough work even under close inspection.
(c) The ultimate cost may be increased.
(d) Dispute over the character and sequence of the work.
(e) Dispute over distribution of ballast.
(f) Dispute over whether or not contractor has fully performed his duty.

On an operated line the same two reasons favorable to ballasting by contract will apply as in the case of a new line.

The same objections are raised and in addition the following are cited:

(g) Some added danger owing to loss of direct control.
(h) Less complete co-ordination between the constructing and operating forces.
(i) Greater interruption to traffic.
(j) Claims for extras on account of interference with the work.
(k) Difficulty of ensuring the maintenance of a surface in the working sector that will prevent surface bending the rail.

Conclusion.

The consensus of opinion expressed is strongly against ballasting by contract in normal times and especially so on an operated track.

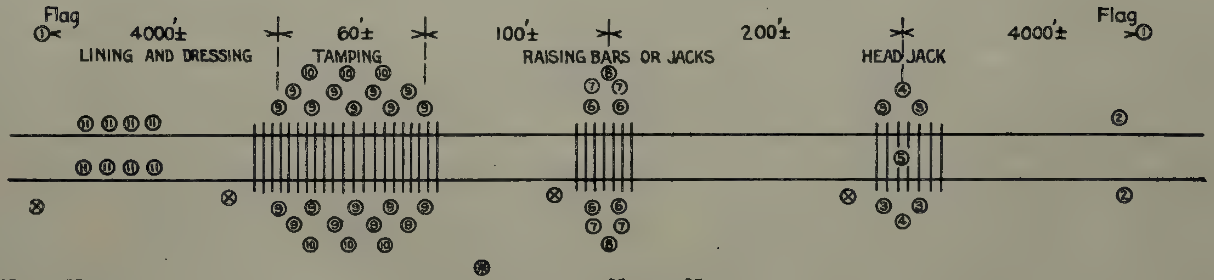
Advocates of ballasting by contract do so largely as an emergency measure because of the greater flexibility of a contractor's organization in changing the rates of pay and so securing labor in time of stress.

The matter is best summed up in the language of one of the men listed as favorable to this method. He says:

"My experience on this and other railroads is that contract ballasting * * * is to a large extent a necessary evil."

Exhibit A.

RAISING TRACK ON HEAVY BALLAST.



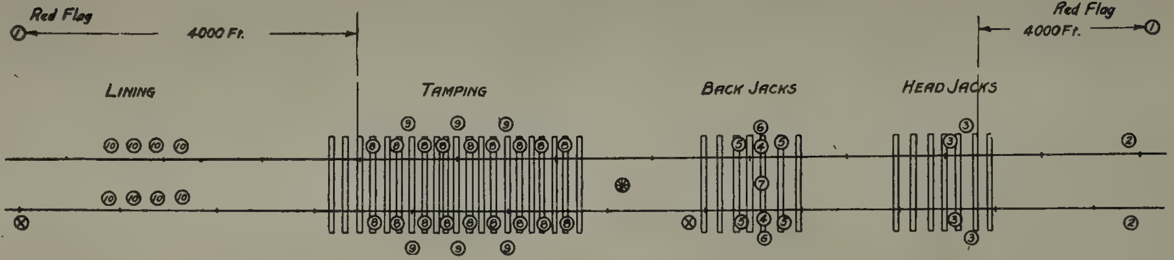
Number.	No. Men.	Force.
1	2	Flagmen.
2	2	Digging Holes for Jacks.
3	4	Head Jacks.
4	2	Spaders.
5	1	Levelman.
6	5	Raising Bars or Jacks.
7	4	Tampers.
8	2	Forkers and Sledgers.
9	18	Tampers with Picks.
10	6	Forkers.

Number.	No. Men.	Force.
11	8	Lining and Dressing.
——	1	Water Carrier.
——	1	Tool Man.
——	1	Time and Material Clerk.
Star	1	Foreman Supervising the Work.
Cross	2	Assistant Foremen Raising Track.
Cross	1	Assistant Foreman Tamping Track.
Cross	1	Assistant Foreman Lining Track.
		Number of Men, 55.
		Total Force, 61.

Exhibit B.

NEW YORK CENTRAL RAILROAD EFFICIENCY METHODS.

RAISING TRACK ON STONE BALLAST.



No. Men.	Force.
2	No. 1—Flagmen.
2	No. 2—Digging Holes for Jacks.
4	No. 3—Head Jacks.
2	No 4—Back Jacks.
4	No. 5—Tampers.
2	No. 6—Forkers and Sledge.
1	No. 7—Levelman.
18	No. 8—Tampers with Picks.
6	No, 9—Forkers.

No. Men.	Force.
8	No. 10—Lining Track.
1	No. 11—Water Carrier.
1	Star—Foreman Supervising the Work.
1	Cross—Assistant Foreman Raising Track.
1	Cross—Assistant Foreman Lining Track.
	Number of Men, 50.
	Total Force, 53.
	Average, 4,500 ft. per day.
	Average Back-Fill, 1,200 cu. yds. per day.

Exhibit C.

The arrangement shown is that which we would consider ideal in case labor conditions were such that sufficient men might be obtained.

It is presumed, of course, that the skeletonizing, renewals and spacing of ties has preceded the work to be done by the forces as shown by this diagram, and on this account by reason of the track being opened up, the territory over which these gangs are working is within slow-speed limits, requiring a speed not in excess of 30 miles per hour, so that the work being done by these gangs does not require a finishing other than is necessary to put the track in shape for 30 miles per hour for passage of trains during the day and the night hours. This stretch of track being protected at all times by proper signals displayed, both during the day and the night.

The lifting gang consists of 60 men, arranged as shown on the diagram. The head jack lifts the track one-half of the total lift and the rear jack makes the remainder of the lift; the head and the rear jack being kept one-half rail length apart at all times, this arrangement insuring the possibility of obtaining a suitable run-off on short notice and does away with the danger of surface-bending the rail by making high lifts at one point. The men shown tamping inside of the rail, tamp only for a very few inches inside of the base of the rail in order that there may be no possibility of the track later becoming centerbound. The lining gang immediately behind the tamping gang merely takes care of the sharp kinks in the track so that the line will be safe for a speed of 30 miles per hour without further attention for three or four days, at which time the surfacing gang will reach the work.

The lifting gang of 60 men work every other day making a lift, lifting about one mile of track during such day's work. On the alternate day this gang drops back behind the surfacing gang and trims the track, such work consisting of shoveling the stone out of the way of the stone ballast line, surfacing up the sub-ballast for the stone ballast line, setting the stone ballast line by the means of a template, trimming and refilling between the ties, carrying excess stone to points where needed in finishing, cleaning ditches and making repairs to farm and highway crossings. Disposition of this gang doing trimming work is also shown on the diagram.

A period of three or four days elapses between the time when the track is lifted by the lifting gang until the same point is reached by the surfacing gang. The track being subjected during this time to the tamping effect of the passing trains, and our specification provides that the track shall be tamped sufficiently well by the lifting gang that the surfacing gang following same will not have to lift the track over 2 inches in surfacing same after traffic has passed over the track for the period of three or four days, as above mentioned. There is, therefore, a space of approximately one or one and one-half miles between the lifting and the surfacing gang. The surfacing gang consists of about

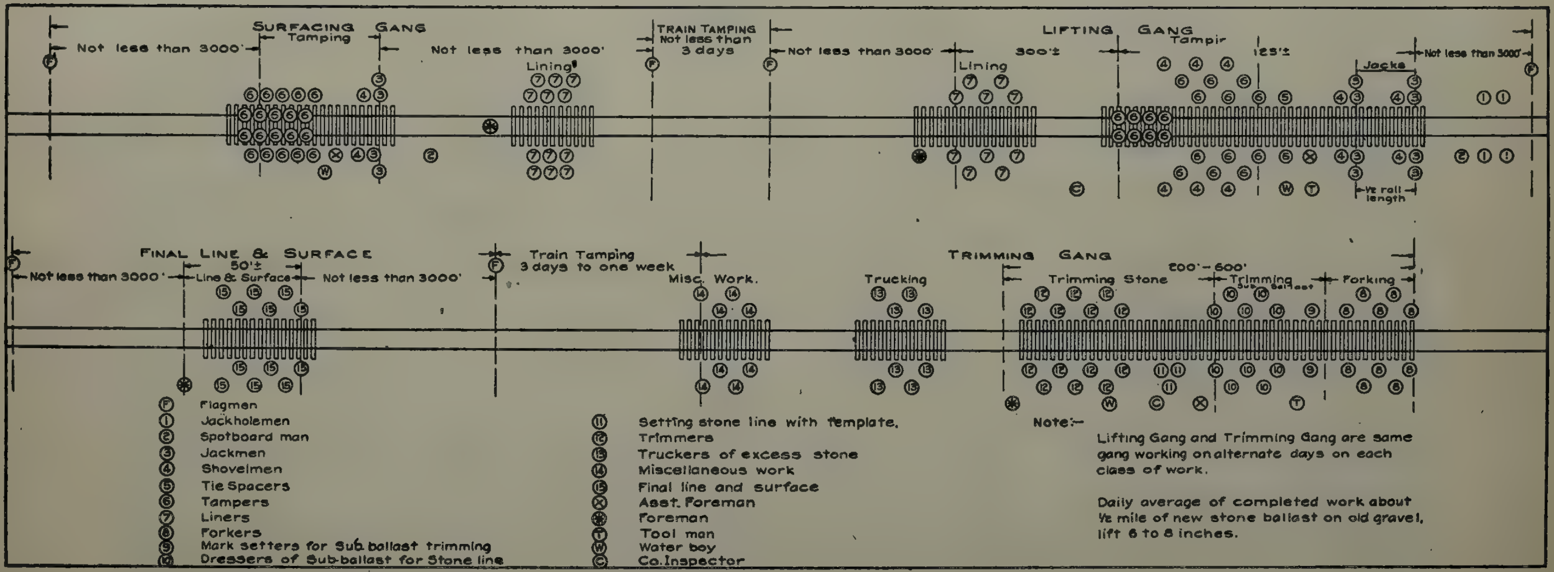
44 men arranged as shown in the diagram. The lining gang shown lines the track ahead of the surfacing gang to the center stakes which have been set by the Engineering corps. The surfacing gang then makes a lift which must not be in excess of 2 inches to bring the track to the proper grade after the passage of three or four days' traffic as above noted.

On alternate days as above mentioned the lifting gang drops back behind the surfacing gang and does the trimming up. The first operation in the trimming being the forking up of the stone off from the ballast section outside of, and on, the stone ballast line; marks are then set showing at what point the sub-ballast section must be lowered or raised before the stone line is put on same. A small gang then follows, putting the subgrade or rather sub-ballast surface in proper shape for the laying of the stone ballast line, which is done by a small gang by means of a template, which fastens over the head of the rail and insures the stone ballast line being at a uniform distance out from the rail. The next operation is the surface trimming and filling in between the ties with the stone ballast. This work completing the work done by the trimming gang. There is a small gang shown, however, whose duty it is to load onto carry cars and to haul back and forth the excess stone for depositing at points where further stone ballast is needed in the trimming. Another small gang is shown whose duty it is to clean sub-ballast out of the ditches and restore farm and highway crossings, etc.

After a further period of from four days to a week has elapsed since the trimming gang has gone over the track, a small gang consisting of about 12 men and the Foreman, go over the track and do the same class of work that would be done by the ordinary section gang following up work of this class, that is, they touch up the line and take care of any small surfacing work that may be necessary. It is possible that with work done by the Company's forces and not by contract, that this latter gang might be dispensed with, as the section gang upon whose section the ballasting work was being done would be expected to do this work. However, as the stone ballast contract calls for finished work, it is up to the contractor to do all the finishing and fine lining necessary, therefore, a gang as above noted is assigned to this work.

The forces disposed of as above outlined should allow the completion of an average of about ½ mile of finished track per day.

Exhibit C.



Note:—

Lifting Gang and Trimming Gang are same gang working on alternate days on each class of work.

Daily average of completed work about ½ mile of new stone ballast on old gravel, lift 6 to 8 inches.

Exhibit D.

GRAND TRUNK RAILWAY SYSTEM.

A typical Ballast Gang in our operation (gravel only being used) consists of:

2 Jackmen.
4 Men jacking (with jacks.)
2 Men casting in ballast for packers.
4 Outside packers.
4 Inside packers.
4 Men tamping.
1 Man with level board.
1 Waterman.
1 Assistant Foreman.
1 Foreman.

(a)

1 Man making holes for track jacks.
2 Men pulling spikes from bad ties.
2 Men with track jack.
2 Men pulling out old ties.
4 Men placing new ties.
4 Men spiking and holding up new ties in track.
4 Men packing outside of ties.
4 Men packing inside of ties.
2 Men with tamping bars for joints.
1 Waterman.
1 Man tightening bolts.
1 Foreman.
1 Assistant Foreman.

Assistant Foreman

2 Men pulling spikes from bad ties.
2 Men removing old ties.
4 Men placing new ties.
4 Men holding in place and spiking new ties.

Foreman

1 Man making holes for track jacks.
2 Men with track jacks.
4 Men packing ballast on outside.
4 Men packing ballast inside.
2 Men tamping joints with bars.
1 Man tightening bolts.
1 Waterman.

(b)

2 Jackmen.
4 Men packing with jacks.
2 Men casting in ballast for packers.
1 Man with level board.
4 Outside packers.
4 Inside packers.
4 Men tamping.
1 Waterman.
1 Foreman.
1 Assistant Foreman.
With Gang of 40 men, double all the men shown except Waterman and Foreman.

Foreman

1 Levelman.
2 Jackmen.
4 Men packing.
2 Men casting.

Assistant Foreman

4 Outside packers.
4 Inside packers.
4 Men tamping.
1 Waterman.

(c)

No rock ballast is used on our lines.

With reference to tie renewals: Tie renewals are made at the time of ballasting.

Exhibit E.

OREGON SHORT LINE RAILROAD COMPANY.

We use as ballasting gangs on a line, which is already in commercial service, when we can get them, as many gangs as we can serve with cars or engines or hauling crews, up to the limit of the output of our ballast pit; the idea being not to keep any track opened up for any considerable time in advance of the gravel dumping.

(a) Single unit ballasting gangs, with us, consist first of a general foreman, next a foreman and gang of thirty men, digging out track and replacing worn out and decayed ties; next a dumping gang, consisting of assistant foreman and six men, who look after the dumping and spreading of the gravel, in connection with the train crew. Next, the raising and tamping gang, which ordinarily consists of a foreman and forty men; and next the finishing and dressing gang, which ordinarily consists of assistant foreman and twenty men.

(b) The only difference on newly constructed lines, which are not filled in with other material, is that the first gang named in the foregoing, which digs out and opens up track, may be dispensed with, and the other gangs slightly reduced in numbers, because of the fact that if the new line is not handling commercial business, there is no necessity for frequently making the track safe for the passage of commercial trains.

(c) I see no difference between the requirements for a gang to use in raising out of face and rock ballasting a line previously ballasted with inferior material, and the requirements for a gang as first mentioned in ballasting a line in operation, because to gain satisfactory results from rock ballast, or any other ballast, the inferior material should be dug out down to the bottom of the ties, and spread on the shoulders, rather than to make the raise and leave the inferior material in place.

Exhibit F.

RICHMOND, FREDERICKSBURG & POTOMAC RAILROAD.

Our organization of a ballast gang for new construction consists of about 100 men, 1 General Foreman, 3 Assistant Foremen, 1 Timekeeper and Commissary Clerk. The gang was subdivided into three separate gangs, 40 men each in the first and second, and 20 men in the third, which put the finishing surface and line on the track.

We have never rock ballasted. With reference to reballasting refer to my report to the Committee on Ballast in Vol. 18, Proceedings, p. 451.

Appendix C.

(5) COMPARATIVE MERIT OF DIFFERENT STONES AND GRAVEL AND OTHER MATERIAL FOR BALLAST.

(6) PHYSICAL TESTS OF BALLAST.

C. J. Coon, Chairman, Sub-Committee.

Under date of July 24, 1917, approximately thirty carriers were requested to list the various ballasts used of each kind in the order of their effectiveness and the answers of sixteen are tabulated in Appendix "G" hereto attached.

At the meeting in March, 1917, the Association approved the recommendation of the Ballast Committee on the order of effectiveness of various kinds of ballast and your Committee has endeavored to obtain from Exhibit "G" the order of effectiveness of the various classes of each kind of ballast as follows:

Conclusions.

(1) *Stone.*
  - (a) Trap rock.
  - (b) Limestone.
  - (c) Sandstone.

(2) *Washed Gravel.*

(3) *Broken Slag* (not granulated).
  - (a) Precious metal slag.
  - (b) Open-hearth slag.
  - (c) Blast furnace slag.

(4) *Pit Run Gravel.*
  - (a) River or stream gravel.
  - (b) Hill gravel (not cementing).
  - (c) Hill gravel cementing.

(5) *Chatts.*
  - (a) Chatts from zinc ore, which is coarse.
  - (b) Chatts from lead ore, which is fine.

(6) *Burnt Clay or Gumbo.*

(7) *Cinders.*
  - (a) Hard coal cinders.
  - (b) Volcanic cinders.
  - (c) Soft coal cinders.

Conclusions.

The results of a large number of "Physical Tests of Road Building Rock" (88 pages) by the U. S. Department of Agriculture, are given in their Bulletin No. 370 and your Committee feels that this bulletin contains very valuable data on the study of stone for ballast.

The following reference is recommended for the Manual, "For results of Physical Tests of Road Building Stone (88 pages), see U. S. Department of Agriculture Bulletin No. 370."

Your Committee obtained from the Library Service Bureau, United Engineering Society, 29 West 39th Street, New York City, a list of publications on "Ballast and Ballasting." "This is not a complete bibliography; it is a continuation of a search made on the same subject in the library of the American Society of Civil Engineers October 10, 1906; references to publications by the American Railway Engineering Association are omitted." A copy of same is attached as Exhibit "H." The former bibliography was published by the American Railway Engineering Association in Volume 8, page 47.

In the study of this subject your Committee obtained from the same library a list of publications on "Physical and Chemical Tests, Road Stone, etc., Especially Weathering Tests, Abrasion Tests, etc.," dated November 22, 1917, copy of which list is attached as Exhibit "I."

Your Committee recommends that no other changes be made in the Physical Tests of Stone for Ballast previously adopted.

Exhibit G.

COMPARISON OF MATERIAL USED FOR BALLAST ON 16 RAILWAY SYSTEMS.

		Stone	Pit Gravel	Washed Gravel	Cinders	Slag	Chatts	Burnt Clay	Chert
C. B. & Q. Ry.	Kind and Size	Very little used.	Clean river gravel used. 15% sand. Top loam stripped off. Gravel mostly used for ballast.		Furnace and locomotive cinders from bituminous and lignite coal used.			Only kind used is from clayey gumbo burnt in open pits.	
A. T. & S. F. Railway	Kind and Size	1. Trap. 2. Flint. 3. Hard limestone. Sizes up to 2½".	Recommend stone maximum size 2½" with 30% sand.		Locomotive cinders from soft coal and volcanic cinders used.	Iron ore slag broken to crusher size.	Have used small quantity of fine zinc chatts.		
	Results	Best results with top dressing of 1" stone.			Latter very preferable.	Very effective.			
Northern Pacific Ry.	Kind and Size		Limit stone to 2½" throwing out larger stone. Loam and clay limited to 5% to 10%. Varies from coarse sand to 50% stone over 2".		Locomotive cinders from soft coal used on branch lines.				

Exhibit G.

COMPARISON OF MATERIAL USED FOR BALLAST ON 16 RAILWAY SYSTEMS—Continued.

		Stone	Pit Gravel	Washed Gravel	Cinders	Slag	Chatts	Burnt Clay	Chert
N. & W. R. R.	Kind and Size	Limestone used and tests made with sandstone or granite. Size ¾" to 2½".	Size of stone not over 2½", while 25% to 35% sand is screened out.	Used in Ohio. Size 2½" to ¾", also size ¾" to ⅜" with no sand.	Engine and coke cinders used.	Slag from Va. and W. Va. Coal and ore, also screened from ¾" to 2½" used.			
	Results	Sandstone and granite found too unsatisfactory for use.		Very poor ballast under heavy traffic. Usable with a little sand for light traffic.		Prefer screened but are discontinuing use of slag.			
Atlantic Coast Line	Kind and Size	Small mileage of crushed granite, and crushed Florida limestone. Size to pass 3" screen and hold on ½" screen.	Unwashed Va. gravel with a small amount of loam and clay used, also a gravel from Alabama free from loam and with 80% stone and 20% sand.	Have used washed gravel of 2 parts stone and 1 part sand. Trying gravel with 3 parts stone. Maximum size stone 1½".	Locomotive cinders from soft coal used.				
	Results	The above has given satisfaction.	The first not as satisfactory as washed gravel. The second so satisfactory that it is hauled 500 miles.						
L. & N. R. R.	Kind and Size	Limestone only used, the sandstone being too soft. Size to pass 2½" ring with dust screened out.	On one division cheek gravel with 10% sand and stone from egg size down used.		Locomotive cinders used.	1. Hard copper slag to generally pass 1½" ring used. 2. Granulated copper slag used. 3. Iron blast furnace slag used.	Fine lead chatts used on St. Louis Division.		Natural chert has much clay and is not used. Washed iron ore chert is delivered by mining companies.
	Results	Should place coarse stone on subgrade and surface with 2" stone.	Very good ballast.		Good on branch lines and side tracks.	1. Good ballast but difficult to load and hard on track tools. 2. Poor ballast. 3. Good ballast and easier to surface than broken stone.	Easy to maintain line and surface.		The latter is very good ballast.

Southern Pacific	Kind and Size	Crushed granite and basalt used. Size crusher run from ½" to 2½". Crushed disintegrated granite size of pea also used.	Clean stream gravel used with ⅓ sand and ⅔ stone. Stone ¼" to 2". A little gravel with 50% sand and 10% silt and 40% stone used.						
	Results	For first both materials give good results. Second packs and drains well.	First used very generally. Second unsatisfactory and drains badly.						
C. R. I. & P. Railway	Kind and Size	1. Blue limestone. 2. Blue trap. 3. Porphyry, very brittle and light color. Use 3" or 4" stone for subgrade with top 6" of 1" stone.	Has about 15% to 25% equal parts of sand and clay. Stone up to 2" size.	If used should have 20% sand with larger stone 1½" size.	Locomotive cinders from soft coal used only on light branches.	Pueblo iron slag used. Hard and brittle. Size 1" to 1½".		Made from black waxy gumbo burned with slack coal. Should be as free from sand as possible.	
	Results	Above sizes hold track and give good drainage.	Sheds water and holds track well when properly drained.		Used for surfacing in very wet weather.	Holds track well after ageing.			
Missouri Pacific Ry.	Kind and Size	1. Limestone. 2. Sandstone. 3. Flint. 4. Granite. Size ½" to 2".	1. River gravel. 2. Hill gravel. 3. Hill cementing gravel. 35% sand, not more than 3% loam. Maximum size stone 1½".	1. Washed river gravel 45% sand and fine gravel. Maximum stone 1½". 2. Washed hill gravel. Maximum 35% sand and 10% gravel under ½". Stone maximum size 1½".	1. Locomotive cinders from soft coal. 2. Furnace cinders from soft coal.	Iron ore slag. In too large pieces and unsatisfactory.	1. Chatts from zinc rather coarse. 2. Lead chatts fine.	Black gumbo burned with old ties in alternate layers.	
	Results	GIVEN IN ORDER OF EFFECTIVENESS.							

Exhibit G.

COMPARISON OF MATERIAL USED FOR BALLAST ON 16 RAILWAY SYSTEMS—Continued.

		Stone	Pit Gravel	Washed Gravel	Cinders	Slag	Chatts	Burnt Clay	Chert
Pennsylvania R. R.	Kind and Size	Some gneiss and fine grained sandstone, but mostly trap used. (Limestone discarded as unsatisfactory.) Size to pass 3" and hold on 1¼" ring.	Loam and sand 10%, stone 90% used. Specified must be free from earth and loam and pass 2½" ring.	Sand excluded and stone ¼" to 2½".	Locomotive and Power Plant cinders from fine anthracite used.	Iron furnace slag. Rough slag must pass 3" ring. Screened slag must conform to size of stone ballast.	Not used.	Not used.	Not used.
	Results		Used on branch lines. Not very satisfactory.	Used on some branch lines.	Use confined to branch lines and sidings.	Seasoned slag is better than fresh. Granulated slag not allowed.			
Pennsylvania Lines—S. W. System	Kind and Size	Limestone only used. Size to pass 2½" and hold on 1" ring.	Small quantity only used, soil is stripped as clean as practicable.	Two kinds used. 1. Less than 5% sand. 2. With 20% sand. Maximum size stone 2".	Locomotive and furnace cinders from soft coal used	Not used.	Not used.	Not used.	Not used.
	Results	Uniformity of size is very important.	Not desirable if washed gravel is obtainable.	Gravel with lesser quantity of sand is better.	Locomotive cinders are the better				
Pennsylvania Lines—N. W. System	Kind and Size	Ohio limestone used. Size to pass 2½" and hold on 1" ring.	Used on some divisions. Maximum size stone 2". Maximum loam and sand 25% to 30%.	Very small amounts have been used for top dressing. Generally uniform in size.	Mostly locomotive cinders from soft coal used.	1. Small amount of crushed and screened slag used. 2. Bank slag used on some important branches. 3. Granulated slag used extensively on side tracks and on unimportant branches.	Not used.	Not used.	Not used.
	Results	Argillaceous dolomite from Dunkirk, Ohio, is the best.	Fairly satisfactory as ballast.	Good dressing but does not bind and hold track well for ballast.	Furnace cinders contain more fine material than locomotive cinders and are less satisfactory.	1. Very satisfactory. 2. Crumbles and drains poorly. 3. Not as good as locomotive cinders.			

N. Y., N. H. & H. R. R.	Kind and Size	Conn. trap rock used. Size to pass 2⅝" screen and hold on 1¼".	Gravel from 17 pits described, varying from 1% to 5% of loam and 10% to 75% of sand Maximum size of stone 2½".	Not used.	Locomotive cinders from soft coal used on branch lines.	Not used.	Not used.	Not used.	Not used.
	Results	Stone should be graduated uniformly. These dimensions are very satisfactory with heavy traffic.	Best gravel used had no loam and less than 40% sand. The latter stood up well under heavy traffic and drained well.		Satisfactory on light traffic branches.				
Erie R. R.	Kind and Size	Trap rock and limestone used. Sizes 1" to 2½".	Gravel with no loam and about 40% sand used.	Not used.	Locomotive cinders from soft coal used.	Crushed and screened hard slag used.	Not used.	Not used.	Not used.
	Results	Drains better when smaller screenings are excluded.	Not desirable for high speed track.		Preferable to furnace or hard coal cinders.	No comment.			
B. & O. R. R.	Kind and Size	Trap rock, granite, limestone used Size to pass 3" screen and hold on 1" screen.	Not more than 2% dust nor 40% of sand. Stone not specified as to size.	Not less than 25% nor more than 35% sand left after washing.	Soft coal locomotive and hard coal furnace cinders used.	Hard slag and granulated slag from Minnesota ore.	Fine chatts from lead ore.		
	Results	NO RECOMMENDATIONS.							
R., F. & P. R. R.	Kind and Size		Not now used except on temporary work.	Have tried three kinds: 1. 22% to 25% sand and small gravel to pass ¼" screen. 2. 14% sand. 3. 7% sand.	Locomotive cinders from soft coal used.				
	Results			The last gives much the best results.					

Exhibit H.

BIBLIOGRAPHY ON BALLAST AND BALLASTING.

Note: This is not a complete bibliography; it is a continuation of a search made on the same subject in the Library of the American Society of Civil Engineers, October 10, 1906; references to material published by the American Railway Engineering Association are omitted.

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1911—Mattis, Geo.
Screening large boulders from ballast.
Ry. Age Gaz., v. 51, p. 1227, Dec. 15, 1911.

Describes a method adopted on one of the roads in the West; half a column.
New self-discharging hopper ballast car.
Amer. Engr. & Railroad Jour., v. 85, p. 48, Feb., 1911.
Car selected from competitive designs submitted by various European builders, for the Buenos Aires Western Railway.
A new type of self-discharging hopper ballasting railway wagon.
Ry. Gaz. Lond., v. 50, p. 416, Apr. 28, 1911.
Illustrated description of cars used on the Buenos Aires Ry.
Reballasting by contract.
Ry. Age Gaz., v. 51, p. 788, Oct. 20, 1911.
Describes method used on the Michigan Central Railroad; half a page.
Self-discharging hopper ballasting railway wagon.
Engineer, v. 112, p. 288, Sept. 15, 1911.
Illustrated description of cars in use on the Buenos Aires Western Railway.
Wagon tombereau de 20-t.
Rev. Gen. des Chemins de Fer, v. 34, pt. 2, p. 389, Dec., 1911.
20-ton ballast cars; description of small gondola cars, with four-shoe, hand lever-brakes, worked by rachet.
Wiener, Lionel.
Les chemins de fer du Brésil.
Revue Gen. d. Ch. d. Fer, v. 34, pt. 2, p. 365, Dec., 1911.
The ballast of the majority of railroads in Brazil is in earth, on account of the prohibitive price of stone ballast.
1912—Clough, A. M.
Handling stone ballast.
Ry. Age Gaz., v. 52, p. 1107, May 17, 1912.
On a method tried on the New York Central Railroad.
Cost of rock ballast.
Ry. Age Gaz., v. 53, p. 314, Aug. 16, 1912.
Actual cost of putting in stone ballast.
Goldbeck, A. T., and Jackson, F. M.
Physical testing of broken-stone ballast.
Ry. & Eng. Rev., v. 51, p. 890, Sept. 28, 1912.
Gives table of results of tests of stone used for ballast on different railroads.
1912—A gravel washing plant for railway ballast; structural details and methods and cost of operation.
Eng. Con., v. 37, p. 341, Mar. 27, 1912.
Illustrated description of a plant located 57 miles from Richmond, Va.
Handling stone ballast.
Eng. Rec., v. 66, p. 318 (1912). One column.
Lindsay, C. E.
Keeping stone ballast clean.
Ry. Age Gaz., v. 53, p. 1193, 1203, Dec. 20, 1912.
One and a half pages; includes illustration of stone ballast screen.
Physical tests of stone ballast. (Editorial.)
Ry. & Eng. Rev., v. 51, p. 899, Sept. 28, 1912.
On the tests made by A. T. Goldbeck and F. M. Jackson.
Stone ballast.
Ry. Age Gaz., v. 53, p. 533, Sept. 20, 1912; Ry. & Eng. Rev., v. 51, p. 855, Sept. 14, 1912.
Report of a Committee of the Roadmasters & Maintenance of Way Assoc.

1912—Stradling, D. W.
Notes on contract ballasting, Missouri Pacific Ry., including tables for calculating volume of ballast applied, also cost and progress, recording forms used.
Eng. Cong., v. 37, p. 332, Mar. 20, 1912. Six pages.

1913—Ballast crushing plant of the El Paso & Southwestern.
Ry. Age Gaz., v. 54, p. 1573, June 20, 1912.
Detailed cost data for furnishing the ballast in the track are given.

The Cafferty-Markle ballast spreader.
Ry. Age Gaz., v. 54, p. 355, Feb. 21, 1913.
Half a page, illustrated.

Clough, A. M.
Placing stone ballast in one lift. (Letter.)
Ry. Age Gaz., v. 54, p. 887, Apr. 18, 1913.
The purposes of the system outlined are, to haul and unload the stone so that it will be put under the track the day on which it is received and unloaded; to distribute the men in the gang in such a way as to check their work; to keep the track in such line and level at all times that slow orders will not be necessary; three-quarters of a page.

Crandall, Chas. Lee, and Barnes, Fred Asa.
Railroad Construction, p. 251.
N. Y., 1913. McGraw-Hill Book Co., 239 West 39th St. $3.
Contains two and a half pages on ballast; states that broken stone is usually given the first place on account of its durability and stability.

1913—Editorial.
Ry. Age Gaz., v. 54, p. 1555, June 20, 1913.
On the influence of the layout of a ballast pit on its economic operation; a quarter of a page.

Editorial note.
Ry. Age Gaz., v. 54, p. 1077, May 16, 1913.
On setting ballast stakes.

Keyser.
Repairing ballast cars.
Railway Age Gaz. (Mech. Edition), v. 87, p. 608, Nov., 1913.
Same. Railway Age Gaz., v. 55, p. 990, Nov. 21, 1913. One page.

Tie renewals and ballasting.
Railway Age Gaz., v. 54, p. 1091, May 16, 1913.

1914—Bowser, J. T.
Why not hold to standard widths of railway roadbed?
Eng. Rec., v. 70, p. 379, Oct. 3, 1914.
Advocating a roadbed on which ballast can be retained in good condition; one column.

Cleaning stone ballast by screening. (Editorial.)
Ry. & Eng. Rev., v. 54, p. 611, Apr. 18, 1914. One page.

Hagersville ballast crushing plant of the Michigan Central.
Ry. Age Gaz., v. 56, p. 385, Feb. 20, 1914.
Detailed costs are given.

Harvey, J. C.
Method of preparation of burnt clay ballast.
Railway Age Gaz., v. 56, p. 521, Mar. 13, 1914.
A description of the process of converting heavy gumbo into ballast.

1914—Howson, E. T.
Recent developments in track construction.
Railway Age Gaz., v. 57, p. 745, Oct. 23, 1914.
Contains one paragraph on ballast.
Improved Mann-McCann Spreader.
Ry. Age Gaz., v. 56, p. 588, Mar. 18, 1914.
The Lawrence snow and ice flanger and ballast spreader.
Ry. Age Gaz., v. 57, p. 758, Oct. 23, 1914.
Half a page, illustrated.
Mahlstedt, C.
Obtaining gravel ballast in State working.
Bull. Inter. Ry. Cong., v. 28, p. 432, May, 1914.
A report of a successful experiment in Germany.
O'Connor, J.
Organization for surfacing track.
Eng. News, v. 72, p. 84, July 9, 1914.
Details of organization for ballasting track; one column.
Shea, W.
Merits of burnt clay ballast.
Railway Age Gaz., v. 56, p. 525, Mar. 13, 1914.
On the use of burnt gumbo ballast.
Tamping track with air power.
Eng. News, v. 72, p. 1219, Dec. 7, 1914.
Describes pneumatic tamping of ballast under railroad ties as tried on the River Division (West Shore) of the New York Central Lines.
Weidel, J.
Operation of a ballast crusher at Coleman, Texas.
Railway Age Gaz., v. 56, p. 912, Apr. 17, 1914.
Gives average cost per cu. yd. of producing crushed rock; plant operated by the Pecos and Northern Texas Ry.
Whitney, H. O.
Operation of a gravel pit.
Ry. Age Gaz., v. 57, p. 757, Oct. 23, 1914.
Wishart, J. G.
Forms for complete rail and ballast records.
Railway Age Gaz., v. 56, p. 378, Feb. 20, 1914.
On the advantages of and methods for keeping such information accurate and up to date.
1915—Ballasting economy.
Electric Railway Jour., v. 46, p. 682, Oct. 2, 1915.
Not verified, as periodical is not in the Library.
Blast furnace slag for railway ballasting.
Engineer, v. 120, p. 395, Oct. 22, 1915.
Plan and side elevation of plant for breaking slag for railway ballast, and brief description.
Campbell, MacRae D.
Portable gravel screening and washing plant.
Ry. Age Gaz., v. 59, p. 345, Aug. 20, 1915.
Church, H. M.
Cleaning stone ballast with screens.
Railway Age Gaz., v. 58, p. 1436, June 18, 1915.
Gives method and unit costs.
The economical operation of a gravel ballast pit.
Ry. Age Gaz., v. 59, p. 117, July 16, 1915.
Two discussions of measures for securing lowest unit costs.

1915—Editorial.
Railway Age Gaz., v. 59, p. 107, July 16, 1915.
On the operation of gravel ballast pits.
Evans, John.
Stone ballasting by contract.
Railway Age Gaz., v. 58, p. 1436, June 18, 1915.
On methods of the Michigan Central Railroad; one page.
Hadley, E. A.
Construction of roadbed and track.
Proc. St. Louis Ry. Club, v. 20, p. 148, Nov. 12, 1915.
Includes reference to the kind of ballast suitable for the roadbed.
Hamilton, P. H.
Characteristics of slag and chat ballast.
Ry. Age Gaz., v. 58, p. 1437, June 18, 1915.
Three-quarters of a page.
Measuring stresses in railway roadbeds.
Eng. News, v. 73, p. 743, Apr. 15, 1915.
Describes an instrument for measuring the pressure of ballast on roadbed under traffic, devised by J. R. W. Ambrose.
Pegram, George H.
Track and roadbed.
Elec. Railway Jour., v. 46, p. 624, Sept. 25, 1915.
Not verified, as periodical is not in the Library.
Rench, W. F.
Important elements in the maintenance of track.
Ry. Age Gaz., v. 58, p. 1439, June 18, 1915.
Contains half a page on ballast cleaning.
Results gained with a ballast dresser.
Railway Age Gaz., v. 59, p. 529, Sept. 17, 1915.
On the use of the Cafferty & Markle ballast dresser, on the Atchison, Topeka and Santa Fe Railroad.
Sellew, William H.
Railway maintenance engineering, p. 172.
N. Y., 1915. D. Van Nostrand Company, 25 Park Place.
Contains a chapter on ballast.
Smoothing a railway subgrade to insure good drainage. (Editorial.)
Eng. News, v. 73, p. 498, Mar. 11, 1915.
On ballasting; one column.
Stimson, E.
The mechanical life of ties as affected by ballast.
Proc. Amer. Wood Preservers Assoc., v. 11, p. 196 (1915).
Mentions the extent to which some forms of ballast increase the abrasive action of the rail upon the tie.
Abstracts Eng. Rec., v. 71, p. 105, Jan. 29, 1915; Ry. Age Gaz., v. 58, p. 161, Jan. 22, 1915; Ry. Rev., v. 56, p. 119, Jan. 23, 1915.
Van Aucken, A. M.
Burnt clay or gumbo ballast.
Railway Rev., v. 56, p. 365, Mar. 13, 1915.
Methods and costs of burning the ballast and different ways of using it.
Vaughan, G. W.
The relative efficiency of various ballast material.
Ry. Age Gaz., v. 59, p. 123, July 16, 1915.
A discussion of the different elements of cost which enter into the ultimate expense to a railroad.
Willard, William C.
Maintenance of way and structures, p. 48.
N. Y., 1915. McGraw-Hill Book Co., 239 West 39th St. $4.
Contains a chapter on ballast.

1916—Ballasting track by contract.
Eng. News, v. 75, p. 828, May 4, 1916.
Method used on Missouri Pacific Ry.; two and a half pages.
Brown, L. W.
Stone ballast plough, North-Eastern Railway.
Jour. Permanent Way Inst., Apr., 1916.
Not verified, as periodical is not in the Library.
Construction of roadbed and track.
Railway Maintenance Engr., v. 12, p. 65, Feb., 1916.
Relation of ties, ballast and subgrade.
Crushed gravel ballast on the Rock Island.
Railway Age Gaz., v. 61, p. 144, July 28, 1916. One page.

1916—Elliott, C. E.
Economical device for spreading rock or gravel ballast.
Engng. & Contracting, v. 46, p. 340, Oct. 18, 1916.
Device used by the Pacific Railway Co. in Southern California, operating one thousand miles of electric interurban lines.
Euger, M. L.
High unit pressures found in experiments of vertical loading through sand.
Eng. Rec., v. 73, p. 106, Jan. 22, 1916.
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The results and experiences gained have been found helpful in planning the more elaborate system of experiments, being conducted at the University of Illinois by the Joint Committee on Stresses in Railroad Track.
Van Auken, K. L.
Track maintenance; ballasting and surfacing.
Railway Rev., v. 59, pp. 379, 696, Sept. 16, Nov. 18, 1916.
Preparation of grade, type of ballast cars, unloading ballast, surfacing, etc.

1917—Cleaning stone ballast on the New York Central R. R.
Railway Rev., v. 60, p. 90, Jan. 20, 1917.
Not verified, as periodical is at the binders'.
Dike, E. R.
Temporary unloading trestle to facilitate handling of ballast.
Elec. Railway Jour., v. 49, p. 257, Feb. 10, 1917.
One column, illustrated.
Double-track work on a busy section of the Erie Railroad.
Eng. News, v. 77, p. 227, Feb. 8, 1917.
Contains a paragraph on ballasting.
Van Auken, Kenneth L.
Track drainage.
Proc. Western Ry. Club, Feb. 19, 1917.
How to prevent subsidence of the ballast into the subgrade; not verified, as periodical is not in the Library.

Exhibit I.

BIBLIOGRAPHY ON PHYSICAL AND CHEMICAL TESTS OF BALLAST, ROAD STONE, ETC.—ESPECIALLY WEATHERING TESTS, ABRASION TEST, ETC.

1897—Rudeloff's method of testing ballast for railroad permanent ways.
    Mittl. Kgl. Techn. Versuchanstalten zu Berlin, 1897, p. 279.
    Bull. Inter. Railway Congress, 1898, Sept., p. 1068.
    Min. Proc. Inst. Civil Engrs., 1897-1898, part 2, vol. 132, p. 423.
  Whittle, C. L.
    Forces which operate to destroy roads, with notes on road stones and problems connected therewith.
    1897, 7 pp.
1902—New York Central & Hudson River Railroad, General Specifications for Grading and Masonry, Jan., 1902, p. 15.
    New York, 1902, Grand Central Station.
  Improvements in tests of macadam materials.
    Engng. Record, 1902, Apr. 19, vol. 45, p. 365.
1903—Hermann, E. A.
    Stone ballast.
    Engng. News, 1903, Dec. 17, vol. 50, p. 532.
  Page, L. W., and Cushman, A. S.
    The testing of road materials.
    U. S. Bureau of Chemistry, Bull. No. 79, Wash., 1903.
  Page, L. W., and Cushman, A. S.
    The U. S. road material laboratory; its aims and methods.
    Proc. Amer. Soc. for Test. Materials, 1903, vol. III, pp. 293-307.
1904—Report of Committee H on standard tests for road materials.
    Proc. Amer. Soc. Testing Mat., 1904, vol. IV, pp. 193-194.
    Proc. Amer. Soc. Testing Mat., 1905, vol. V, pp. 102-103.
    Proc. Amer. Soc. Testing Mat., 1906, vol. VI, pp. 82-84.
  Owen, J.
    Highway construction in the United States.
    Trans. Amer. Soc. Civil Engrs., 1904, vol. 54, part F, pp. 105-116.
1905—Third Annual Report of the State Board of Public Roads of the State of Rhode Island, Jan., 1905, p. 26. Providence, R. I., 1905.
    Table showing results of laboratory tests on Rhode Island rocks.
1906—Baldwin, A. S.
    In "Railway organization and working," p. 160, Ballast.
    Ed. by E. R. Dewsnup, Chicago, 1906.
    University of Chicago Press. $2 net.
  Cushman, A. S.
    The development of the test for the cementing value of road material.
    Min. Eng., 1906, Dec., vol. XXXI, p. 460.
    Abst. from Proc. Amer. Soc. for Testing Materials, 1906, vol. VI, pp. 525-31 (tests made by L. W. Page in co-operation with the Massachusetts Highway Commission).
  Gillette, H. P.
    Economics of road construction.
    2d Ed., New York, 1906. Engineering News Publ. Co. $1.
  Wormeley, P. L., Jr.
    Notes on the hardness and abrasion tests of road materials.
    Proc. Amer. Soc. Testing Mat., 1906, vol. VI, pp. 532-536.

1907—Grinling, A. J.
Permanent way, its construction and maintenance.
Min. Proc. Inst. Civil Engrs., London, 1907, Part I, vol. 167, p. 333.
Lord, E. C. E.
Examination and classification of rocks for road building, including the physical properties of rocks with reference to their mineral composition and structure.
U. S. Office of Public Roads, Bull. No. 31, Wash., 1907.
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1908—Standard toughness test for macadam rock. Standard abrasion test for road material.
Proc. Amer. Soc. Testing Mat., 1908, vol. VIII, pp. 197-200.
Standards of track construction on American railways.
Engng. News, 1908, June 4, vol. 59, p. 607.
Track and ballast.
R. R. Gazette, 1908, Mar. 13, vol. 44, p. 363.
Greenman, R. S.
The acceptance of stone for use on roads based on standard tests.
Engng. Rec., 1908, July 11, vol. 58, p. 44.
1908—Quimby, H. H.
Shearing values of stone and concrete.
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Track and ballast.
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On the supporting power of track ballast.
Zeits. Oesterr. Ing. u. Architekten Vereins, 1908, July 17, vol. 60, p. 470.
Tratman, E. E. R.
Railway track and track work.
3d Ed., 1908. Engng. News Publ. Co. $3.50 net.
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Engng. Contract., 1909, Sept. 1, vol. XXXII, p. 184.
Engng. Record, 1909, July 31, vol. 60, p. 120.
Roadmasters' and Maintenance of Way Association.
Report of the Committee on comparative value of crushed stone, furnace slag, chats, gravel or burnt gumbo as ballast under heavy traffic.
Proc. R. & M. of W. Assoc., 1909, vol. XXVII, p. 29.
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Blackwelder, E.
The new road ballast of U. P. R.
Wisconsin Engr., 1909, Feb., vol. XIII, p. 107.
1910—Stone for macadamized roads in Los Angeles.
Engng. News, 1910, July 14, vol. 64, p. 59.
Armstrong, A. F.
Testing materials for use in highway construction.
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Fletcher, A. B.
Road materials and some simple rules for testing them.
Canad. Engr., 1910, June 16, vol. 18, p. 612.
1911—Experiments on the Pennsylvania R. R. to determine the proper depth of stone ballast and the value of sub-ballast.
Engng. News, 1911, Aug. 24, vol. 66, p. 228.

1911—Granite pavement.
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Road construction and maintenance, an informal discussion.
Trans. Amer. Soc. Civil Engrs., 1911, vol. 73, pp. 92-133; 1912, Dec., vol. 75, pp. 576, 580, 583.

1912—The freezing test of stone.
Canadian Engr., 1912, Dec. 5, vol. XXIII, p. 833.
The physical properties of rock for road building.
Engng. Contract., 1912, Aug. 7, vol. 38, p. 151.
(Tests made at the U. S. Office of Public Roads.)
Physical testing of broken stone ballast.
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State of New York: Report of the State Commission of Highways, transmitted to the Legislature Feb. 15, 1912, p. 418. Albany, 1912.
Results of tests on road building stone in New York State.
Standard abrasion test for road material.
Proc. Amer. Soc. Testing Mat., 1912, vol. XII, pp. 334-335.
Stone ballast.
Railroad Gazette, 1912, Sept. 20, vol. 53, p. 533.
Goldbeck, A. T., and Jackson, F. M.
Physical testing of broken-stone ballast.
Railway & Engng. Rev., 1912, Sept. 28, vol. 51, p. 890.
Elec. Rainway Jour., Nov. 30, 1912, vol. 40, p. 1118.
Siefer, F. M.
Ballasting with lava deposits.
Engng. Record, 1912, Jan. 27, vol. 65, p. 100.

1913—Specifications for granite block paving.
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Page, L. W.
Relation between the tests for the wearing qualities of road-building rocks.
Proc. Amer. Soc. Testing Mat., 1913, vol. XIII, pp. 983-995.

1914—Report of Committee D-4 on standard tests for road materials.
Proc. Amer. Soc. Testing Mat., 1914/I, vol. XIV, pp. 374-377; 378, 379-380, 381-382.
Proposed provisional test for the determination of the apparent specific gravity of rock. Proposed provisional test for the determination of the absorption of water per cubic foot of rock. Proposed provisional method for making a mechanical analysis of broken stone or broken slag.

1914—Crosby, W. W.
Testing granite paving blocks.
Municip. Jour., 1914, July 16, vol. XXXVII, p. 78.
Lichtner, W. O.
A simple compression machine for testing structure materials.
Proc. Amer. Soc. Testing Mat., vol. 14/II, pp. 535-540.

1915—Report of Committee D-4 on standard tests for road materials.
Proc. Amer. Soc. Testing Materials, 1915, vol. XV/I, pp. 325-331.
Gates, A. O.
Kick vs. Rittinger: an experimental investigation in rock crushing, performed at Purdue University.
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Rodgers, M. K.
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Appendix D.

(2) BALLAST SECTIONS, WITH PARTICULAR REFERENCE TO SUB- AND TOP-BALLAST.

R. C. White, Chairman, Sub-Committee.

Your Committee made a composite drawing of the ballast sections of ten principal roads as shown on following page. More ballast sections would have been included except that the additional sections seemed to the Committee to confuse the drawing rather than clarify it.

Through this composite drawing was drawn in red the outlines of the Class A track sections recommended by the Committee for 24 inches of ballast to indicate to the members of the Association how the proposed new section compares with other sections now in use.

Your Committee feels that the Class A section should have 24 inches of ballast under the tie as compared with 12 inches shown in the 1915 Manual, page 55.

To agree on all the points at one time is rather difficult and, therefore, the Committee divided the section into its parts in the following diagram for the purpose of reaching a conclusion on each part separately.

Conclusions.

Your Committee recommends the ballast cross-section as shown on page 714 be adopted for "Class A track with 24 inches of Ballast."

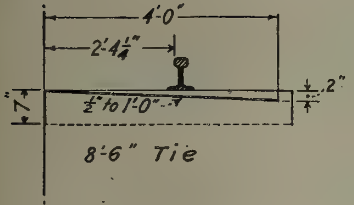


FIG. I

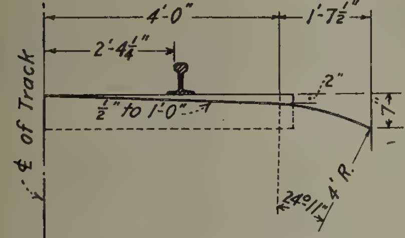


FIG. II

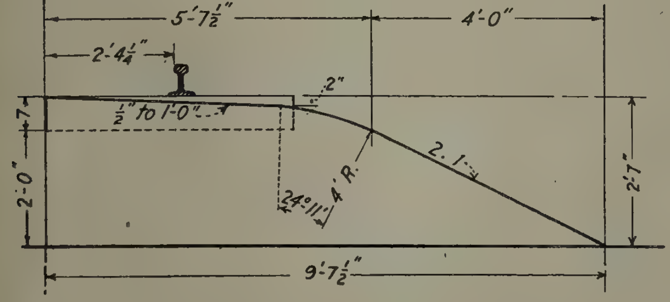
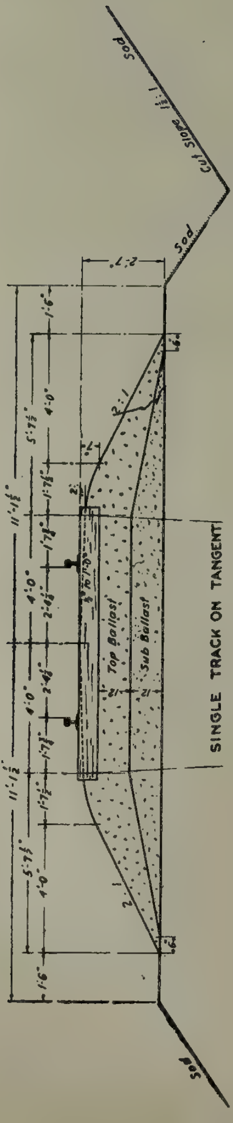
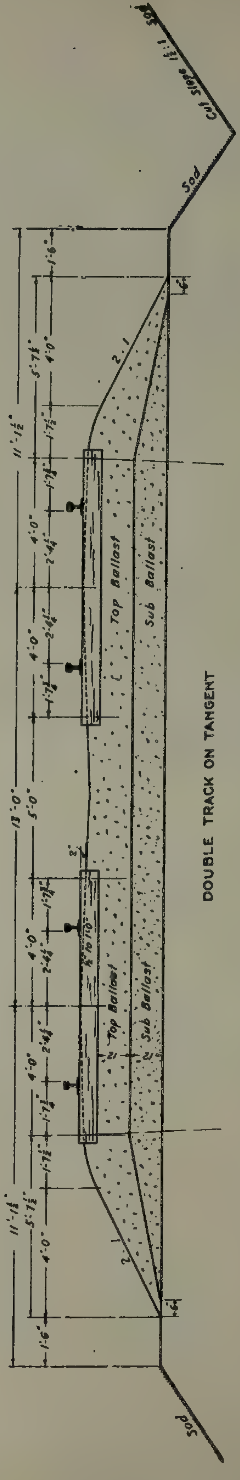


FIG. III

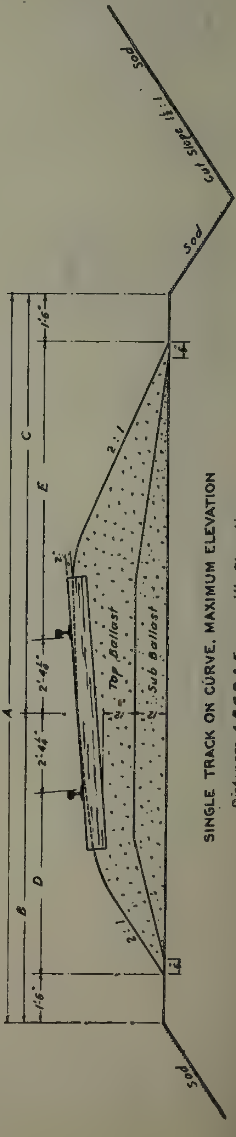
A.R.E.A.
Committee on Ballast
Development of Outline of Recommended Ballast Section
For Stone Ballast on Class A Road
Depth of Ballast 24 in.



SINGLE TRACK ON TANGENT



DOUBLE TRACK ON TANGENT



SINGLE TRACK ON CURVE, MAXIMUM ELEVATION

Distances A.B.C.D & E vary with Elevation

Appendix E.

SPECIFICATIONS FOR STONE BALLAST.

PENNSYLVANIA LINES WEST OF PITTSBURGH.

INSPECTION.

Access to Works.

1. Inspectors representing the Purchaser shall have free entry to the works of the manufacturers at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the ballast is being furnished in accordance with the terms of these specifications.

Place for Tests.

2. Such tests as are deemed necessary shall be made at a Testing Laboratory selected by the Purchaser, but visual inspection shall be made at the place of manufacture prior to shipment as often as considered necessary.

Defect Found After Delivery.

3. As it is impracticable to inspect all the ballast loaded in cars, carloads of defective material arriving at the site for unloading, and not previously inspected, shall be rejected and returned to the manufacturer, who must pay the freight charges both ways.

MATERIAL.

Kind.

4. The kind of material which shall be used for making stone ballast shall be "trap rock" and "limestone."

PHYSICAL REQUIREMENTS.

Physical Qualities.

5. Tests shall be made to determine:
    - (a) Weight.
    - (b) Water Absorption.
    - (c) Percentage of Wear.
    - (d) French Coefficient of Wear.
    - (e) Hardness.
    - (f) Toughness.
    - (g) Cementing Value.
    - (h) Crushing Strength.

Method of Testing.

6. The physical qualities shall be determined by the standard "Methods for the Determination of the Physical Properties of Road-building Rock" (Bulletin No. 347) of the United States Department of Agriculture, Office of Public Roads and Rural Engineering, with the addition of compression test adopted for stone ballast tests by the American Railway Engineering Association.

Pieces for Testing.

7. The description of the pieces required for a single test is as follows:

(a) For "Weight," a fragment of the rock weighing approximately 10 grams (0.35 oz.) and representing as nearly as possible an average of the entire sample.

(b) For "Water Absorption," the same test pieces as in (a).

(c) For "Percentage of Wear," 5 kg. (11 lbs.) of freshly broken fragments of stone 6.35 mm. (¼ inch) and 12.7 mm. (½ inch) in size, numbering about 50 pieces, but not exceeding 60, nor being fewer than 40 pieces.

(d) For "French Coefficient of Wear," no extra sample.

(e) For "Hardness," a piece of solid rock from which a cylindrical core, perpendicular to the bedding plane of the rock, 25 mm. (0.98 inch) in diameter and about 10 cm. (3.94 inches) long can be cut with a diamond core drill and faced off.

(f) For "Toughness," a piece of solid rock from which a cylindrical core perpendicular to the bedding plane of the rock, 25 mm. x 25 mm. (0.98 inch x 0.98 inch) can be cut with a diamond core drill, and the ends ground plane.

(g) For "Cementing Value," ½ kg. (1.1 lbs.) of stone which can be crushed to pea size.

(h) For "Crushing Strength," a piece of solid rock from which a cylinder 50.8 mm. x 50.8 mm. (2 inches x 2 inches) can be cut by means of a diamond core drill, and accurately faced off on each end.

Temperature of Test Pieces.

8. The temperature of the test pieces shall be between 5 and 40 degrees Centigrade (41 and 104 degrees F.).

Physical Values.

9. Other things being equal, the *maximum* or *minimum* results, as indicated, will govern in selecting stone for ballast, the figure named being the limit:

	Trap.	*Limestone.*
(a) A minimum "Weight per Cubic Foot" in pounds	180	160
(b) A maximum "Absorption of Water per Cubic Foot" in 96 hours, in pounds..................	0.35	2.20
(c) A maximum "*Percentage of Wear" of........	2.00	5.00
(d) A minimum "French Coefficient of Wear" (40 divided by Per Cent. of Wear) of............	20	8
(e) A minimum "†Coefficient of Hardness" of........	18	14
(f) A minimum "‡Toughness" of	21	7
(g) A maximum "°Cementing Value" of	10	75
(h) A minimum "Crushing Strength in Pounds per Square inch" of	25,000	10,000

---

*The test pieces in Clause 7-(c), after thorough drying, are placed in Deval cast iron abrasion cylinders, 20 cm. (7⅞ inches) in diameter, which are revolved at the rate of 30 revolutions per minute for 10,000 revolutions for each test, after which the stones are thoroughly washed, dried and weighed, and the percentage of dust or detritus by weight that will pass through a screen with a 1.6 mm. ($\frac{1}{16}$ inch) mesh is considered the percentage of wear.

†The test piece in Clause 7-(e) is subjected to the grinding action of crushed quartz sand, not more than 5 per cent. of which will be retained on a No. 30 sieve and not more than 25 per cent. of which will pass a No. 40 sieve, fed upon a revolving steel disk against which the test piece is held perpendicularly with a pressure of 1250 grams (2.8 lbs.). When the disk has made 1000 revolutions, at the rate of 30 per minute, the loss in weight of the sample is determined and the test repeated with the specimen reversed, and an average of the loss in weight taken. The Coefficient of Hardness is expressed by $H = 20 - \frac{1}{3}$

w, in which *w* represents the loss in weight of the specimen stated in grams per 1000 revolutions.

[‡] The test piece in Clause 7-(f), after drying, is held on an anvil in the Page impact machine, like a miniature pile driver, under a plunger with sphere-shaped striking surface of 1 cm. (0.39 inch) radius, which is struck by a hammer, when released, weighing 2 kg. (4.4 lbs.). The test begins with a 1 cm. (0.39 inch) fall of the hammer for the first blow, and continues with an increased fall of 1 cm. for each succeeding blow until the test piece fails, the number of blows and the height being the same and representing the toughness of the rock.

[°] The test pieces in Clause 7-(g), with 18 per cent. of water, are given 5000 revolutions, at the rate of 30 per minute, in a ball mill which contains two steel shot weighing 9.07 kg. (20 lbs.) each, and the resulting dough is then made into 6 cylindrical briquettes 25 mm. (0.98 inch) in diameter and 25 mm. in height, and formed under a pressure of 132 kg. per square cm. (1877.5 lbs. per square inch), after which they are allowed to dry 20 hours in air, 4 hours in a hot-air bath at 100° C. (212° F.) and then cooled for 20 minutes in a dessicator, and immediately tested.

The low end of a ½ kg. (1.1 lb.) flat end plunger is pressed, by means of two spiral springs, upon the briquette standing on the anvil, after which it is struck by a 1 kg. (2.2 lb.) hammer 60 blows per minute, operated by a cam whose rise is such as to give an effective drop of 1 cm. (0.39 inch) to the hammer, and each blow recorded on a drum which makes a complete revolution in 100 revolutions of the cam.

The number of blows necessary to destroy the resilience of the briquette, so that no reaction is recorded on the drum, is the measure of the cementing value of the rock, the average of five determinations being taken.

Acceptance Requirements.

10. (a) Tests may be made from time to time at the option of the Purchaser, and especially when new strata are being opened up for crushing into ballast.

(b) Each stratum of a quarry shall be tested separately and not averaged with any other stratum.

(c) For obtaining the values for physical tests in Section 9, the average results on the numbers of specimens stated in the following table shall be taken:

Kind of Tests	Weight.	Absorption.	Percentage of Wear.	Hardness.	Toughness.	Cementing Value.	Crushing Strength.
Numbers of Tests.	5	5	2	5	10	10	5

(d) If the rock from a quarry or from any single stratum in a quarry should not meet all the requirements in one or more kinds of tests, the Purchaser may accept the product if he considers that the quality values of the other kinds of tests are predominant.

(e) It is expected that only such ballast as will fulfill all the terms of the specifications will be shipped, unless a written order of exception shall have been given by the Purchaser.

DETAILS OF MANUFACTURE.

Size.

11. (a) Stone ballast must be crushed or broken, as far as possible, into uniform cubes that will pass in any position through a 2½-inch ring, and will not pass through a 1-inch ring.

(b) If the screen is of such shape that slabs longer than 2¾ inches drop through the meshes, the manufacturer must have them broken by hand at the place of loading.

Cleaning.

12. The ballast shall be free from dirt, dust or rubbish. When the rock is of such a nature that it does not become clean without preliminary scrubbing, a scrubbing machine shall be provided at the quarry.

Unit of Quantity.

13. Stone ballast will be ordered and paid for by the net ton, in carload lots.

....
Chief Engineer M. of W., South West System.

....
Chief Engineer M. of W., North West System.

....
Chief Engineer M. of W., St. Louis System.

Issued
Jan. 21, 1910.
Revised
Nov. 9, 1917.
Jan. 1, 1918.

REPORT OF COMMITTEE VIII—ON MASONRY.

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F. P. SISSON,
J. E. SMITH,
JOB TUTHILL,
B. A. UNDERWOOD,
Committee.

To the American Railway Engineering Association:

Your Committee on Masonry during the past year held two meetings of the whole Committee at Chicago, one on December 4, 1917, the other January 22, 1918. Meetings of the various Sub-Committees were held at different times during the year. The meetings were not as well attended this year as last, mainly on account of the war.

The following Sub-Committees were appointed to deal with the subjects assigned by the Board of Direction:

Sub-Committee (1)—Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.

M. S. Ketchum, Chairman; H. A. Cassil, A. E. Owen, W. M. Ray.

Report on this subject is given in Appendix A.

Sub-Committee (2)—(a) Report on cost and method of constructing concrete piles and make recommendations on how and where to be used.

(b) Present additional typical designs for concrete piles for different loading and rules for driving under various conditions and loading.

C. P. Richardson, Chairman; John C. Beye, C. S. Coe, C. S. Davis, F. P. Sisson.

Report on this topic appears in Appendix B.

Sub-Committee (3)—Continue study of typical designs of foundations for piers, abutments, retaining walls and arches in various soils and depth of water (not including pneumatic foundations.)

J. J. Yates, Chairman; R. Armour, J. L. Harrington, Richard L. Humphrey, J. E. Smith.

Report on this subject is given in Appendix C.

Sub-Committee (4)—Report upon the wisdom of the use of blast furnace slag in reinforced concrete work, taking into special consideration its probable duration.

W. S. Lacher, Chairman; T. L. Condron, J. K. Conner, W. K. Hatt, Noah Johnson.

In Appendix D a report is made on this subject.

Sub-Committee (5)—Report on designs and recommended specifications for construction of concrete culvert pipe.

Job Tuthill, Chairman; L. J. Hotchkiss, W. M. Kinney, G. H. Scribner, Jr., B. A. Underwood, G. E. Boyd.

Appendix E contains a report on this subject.

SUGGESTIONS FOR FUTURE WORK.

1. Preparation of new specifications for plain and reinforced concrete and steel reinforcement.
2. An investigation of different methods of depositing concrete under water and disintegration of concrete and corrosion of reinforcing material in connection with use of concrete in sea water.
3. Preparation of specifications for slag concrete.

Respectfully submitted,

The Committee on Masonry.

Appendix A.

(1) REVISION OF MANUAL.

M. S. Ketchum, Chairman, Sub-Committee.

The Sub-Committee on Revision of Manual have the following recommendations to make:

To the Classification of Masonry on page 247 should be added under the column headed "Dressing, Face or Surfaces," the different finishes of concrete, viz., spaded, rubbed, faced, unfaced, washed, acid treated, sand blast, tooled. This should be placed opposite "Bridge and Retaining Wall and Arch." Opposite "Culvert" "spaded" should be placed.

On page 248 the definitions should be changed to agree with the definitions given in the adopted Specifications for Cement.

On page 249 under "Dressing" the definitions of concrete surface finishes as follows should be added:

Spaded Finish.—Having surface formed by spading coarse aggregate back from the form into the mass concrete, so as to bring a surface of mortar next to the form.

Rubbed Finish.—Having surface treated by rubbing with Carborundum or Cement Bricks, or Wooden Floats to remove all form marks and irregularities.

Faced Surfaces.—Having surface formed by placing a special aggregate not less than one inch next to the forms and contiguous with the body concrete.

Unfaced Surface.—Having surface formed by careful grading of the entire mass mixture and spading mixture to prevent voids leaving the coarse aggregate next to the forms.

Washed or Scrubbed Finish.—Having surface formed by rubbing or scrubbing to expose the aggregate.

Acid Treated Finish.—Having surface formed by dissolving cement with acid together with scrubbing to expose the aggregate.

Sand Blast Finish.—Having surface formed by the wearing effect of the sand blast.

Tooled Finish.—Having surface formed by dressing with bush hammer, crandall or other desired tool to a uniform depth and finish.

Page 252 should show after Masonry Specifications the new Specifications for Cement in accordance with Supplement to the Manual, Vol. 19, No. 197, July, 1917.

Page 281, Specifications for Plain and Reinforced Concrete and Steel Reinforcement, need revision. The Committee recommends that the matter of preparing a new specification be referrd to a Sub-Committee for next year's work.

Page 293, Method of Depositing Concrete under water, and page 294, Disintegration of Concrete and Corrosion of Reinforcing Material.

The Committee recommends that this subject be taken up by a Sub-Committee in connection with the general subject of the use of concrete in sea-water.

After the section entitled "Monolithic Construction" on page 292 should be added the adopted report on design of retaining walls, Vol. 19, No. 197, July, 1917. After this and before "Waterproofing of Masonry" should be placed the subject "Adopted Specifications for Surface Finish of Concrete," Vol. 19, No. 197, July, 1917.

Appendix B.

(A) REPORT ON COST AND METHOD OF CONSTRUCTING CONCRETE PILES AND MAKE RECOMMENDATIONS ON HOW AND WHERE TO BE USED.

(B) PRESENT ADDITIONAL TYPICAL DESIGNS FOR CONCRETE PILES FOR DIFFERENT LOADING AND RULES FOR DRIVING UNDER VARIOUS CONDITIONS AND LOADING.

C. P. Richardson, Chairman, Sub-Committee.

Your Committee, during the past year, has revised the definitions, specifications and information as to the manufacture and use of concrete piles which was submitted last year and presents with other data typical plans for their construction. The Committee has not attempted to go into the details of design, as each condition of loading and of sub-soil demands special designs.

(I) Advantages of Concrete Piles.

In general, the more important advantages gained by the use of concrete piles are as follows:

(1) Foundations can be constructed above ground water level.

(2) As their size is not limited, piles of large diameter may be used in confined areas to reduce size of foundation and increase supports at points of greatest pressure.

(3) Concrete Piles may be used in trestles where the height is such as to permit their use, making possible a permanent structure at a considerable less cost than the ordinary type of pier bridge.

(4) Concrete Piles may be used to advantage for sheet piling for docks and wharves where lateral loads as well as vertical loads are to be resisted.

(II) Classification and Description of Concrete Piles.

Concrete piles may be properly divided into two classes:

(A) Pre-molded piles. Piles which are molded previous to driving.

(B) Molded-in-place piles. Piles which are molded in holes in the ground.

(A) PRE-MOLDED PILES.

(a) *Suitability.*—There are many patented piles that are now available, many of which vary in some degree from the types submitted, each one having its particular advantages for some classes of work.

The more common shapes used are the square and octagonal sections, depending upon the style of structure the piles are to carry. The square pile may best be used where a maximum top section is required to distribute the load. The octagonal pile, by reason of its comparative constant diametric section, presents the most suitable shape for general conditions. All shapes are used in the uniform section and in the tapered pile.

The uniform section pile should be used when the pile rests on solid rock or hardpan, or is driven through sand or other similar material which is subject to flow on account of future excavations or from other causes, tending to cause the piles to act as a column. The uniform section pile is more commonly used for all purposes on account of its greater strength for handling and lower cost of construction.

The tapered pile possesses advantages over the uniform section pile when conditions require a close spacing, as its smaller volume causes less displacement of surrounding soil and piles. In general the tapered pile can be driven advantageously in all cases where the soil is clay or similar material, where skin friction will serve as a factor in the bearing power of the pile.

(b) *Design and Construction.*—The typical designs for concrete piles, accompanying specifications for construction of concrete piles furnish, in the opinion of your Committee, a sufficient variation to give information in regard to design of pre-molded piles that may be suitable for various classes of work. In general, piles which are designed to withstand handling are of sufficient strength for driving. The length, design and amount of steel reinforcement required depend upon the following factors:

(1) The load which the pile is to carry.
(2) The nature of the soil into which it is to be driven.
(3) Whether the pile acts as a single column or whether skin friction may be obtained.
(4) Forces to which the pile is subjected in handling.
(5) The method employed in driving, including the use of the water jet.

The forms for concrete piles are generally supported on skids and collapsible, the bottom being left under the piles until they are sufficiently seasoned to permit turning on the skids.

The cost of constructing pre-molded piles depends upon the requirements as to design and on the manufacturing facilities.

The total cost of constructing and driving pre-molded concrete piles varies from 75 cents to two dollars per linear foot, with an average price of about $1.00 per foot, varying with the conditions, length and number of piles made, as shown by tables published on page 824, Vol. 16, of the Proceedings.

Where the ordinary method of sheltered curing is employed, piles should be seasoned not less than twenty-eight to forty days before handling and driving, depending upon the amount of driving expected and the season of the year when the piles are made.

The use of steam or other similar methods may be used to reduce the period of seasoning, or as a means of maintaining a uniform seasoning temperature during the winter season of the year.

SPECIFICATIONS FOR CONSTRUCTING PRE-MOLDED CONCRETE PILES.

1. Piles shall be made in accordance with the dimensions shown on the drawings.

2. The workmanship and materials shall be in accordance with the Specifications for Plain and Reinforced Concrete and Steel Reinforcement of the American Railway Engineering Association, with the following modifications:

Aggregates.

3. The coarse aggregate shall consist of material such as crushed stone or gravel varying in size from one-fourth (¼) inch to three-fourths (¾) inch.

Proportions.

4. The proportions of the concrete shall be one part cement, two parts fine aggregate and four parts coarse aggregate.

Forms.

5. The forms shall be supported vertically or on skids sufficiently close to prevent sagging of forms.

Reinforcement.

6. The longitudinal and transverse reinforcement shall be assembled and securely wired together in accordance with plan before being placed in form. Care shall be taken to maintain the proper position of reinforcing unit in the form until concrete has been placed and compacted.

Freezing Weather.

7. In freezing weather concrete materials shall be stored, and mixing and placing shall be done in a building maintained at a temperature of not less than 40 degrees Fahrenheit. Piles shall not be exposed to a lower temperature for at least 10 days after forms are removed.

Curing.

8. Where ordinary method of sheltered curing is employed, piles shall be seasoned for a period of not less than three days before being moved on the skids and not less than twenty-eight days before handling and moving to the site or driving. No method of accellerated seasoning shall be used until approved by the Engineer.

Marking.

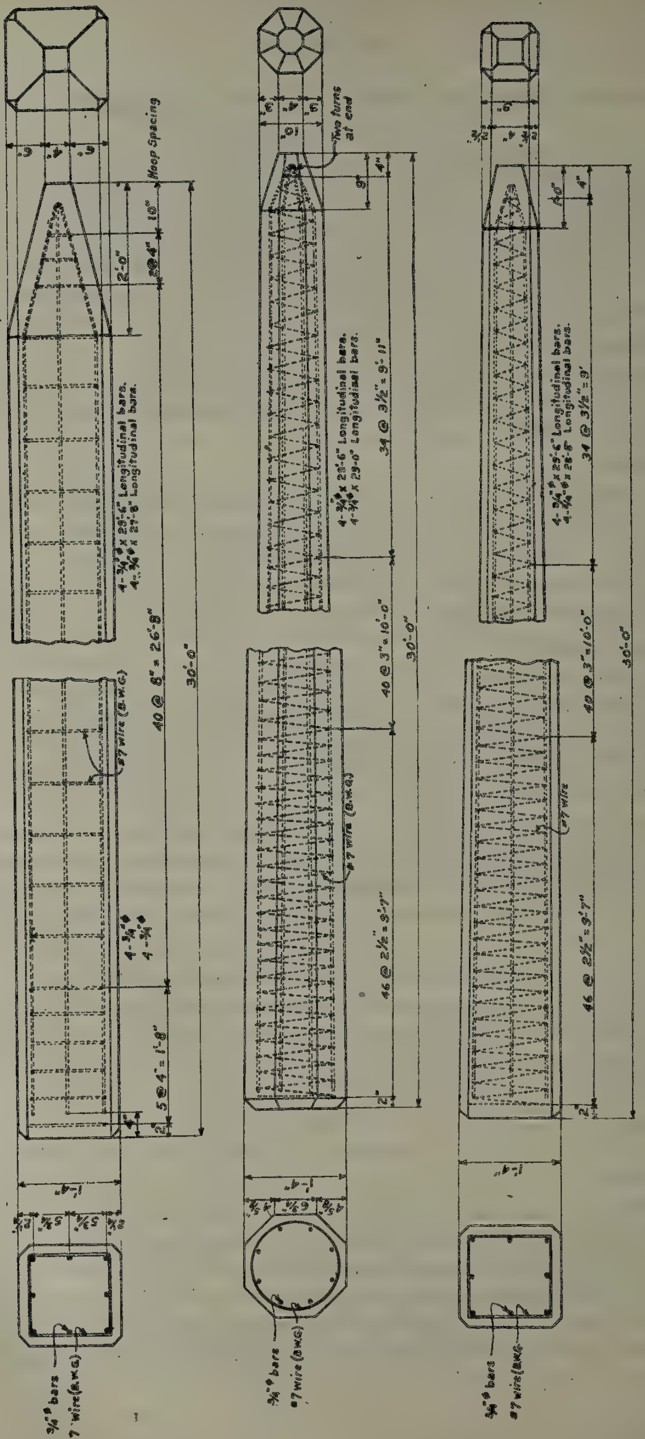
9. Each pile shall be stamped or marked with the date of its manufacture.

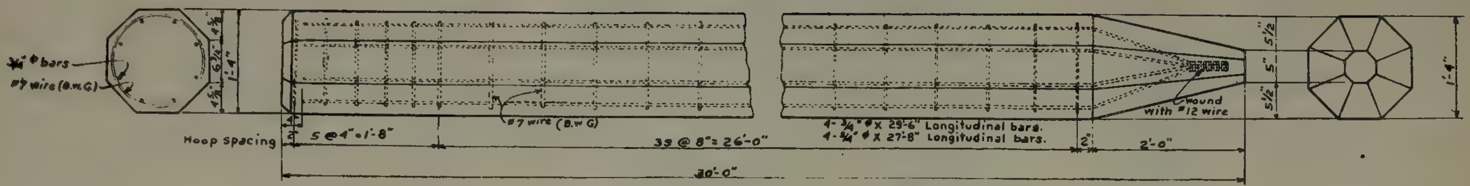
Handling.

10. Piles shall be handled carefully, avoiding any dropping or heavy jarring while in horizontal positions.

The following plans and details are presented as information drawn from the study of a large number of plans and records, which may serve as a guide in the design of concrete piles for ordinary conditions. Piles which are to act as columns should be designed as columns:

TYPICAL CONCRETE PILE SECTIONS.





Length of pile	Longitudinal Reinforcement		Transverse Reinforcement.	
	Detail	Weight per foot.	Hoop	Spiral
20' to 25'	8-5/8"ϕ Bars.	8.34 lbs.	Six spaces from butt end at four (4) inches center to center; balance at eight (8) inches center to center, or other equivalent section of steel per lineal foot of pile.	Wire wound spirally around longitudinal bars with Spacing as follows:- 1/3 Length of pile, Butt end 2½". 1/3 " " ", Middle Section 3". 1/3 Length of pile, point end 3½".
26' to 30'	8-3/4"ϕ Bars.	12.02 lbs.		
31' to 35'	8-3/4"ϕ Bars.	14.78 lbs.		
	* 8-5/8"ϕ Bars			
36' to 40'	8-7/8"ϕ Bars	20.[illegible] lbs.		
	* 8-3/4"ϕ Bars		Note: Round or square bars of equivalent section may be used. Hoop or spirally wound transverse reinforcement may be used in all types of piles.	
* Placed in middle third of length				

Explanatory Notes.

Longitudinal Reinforcement.

Piles not exceeding thirty (30) feet in length are reinforced with eight (8) longitudinal bars of which four (4) are cut so as to stop at the beginning of the tapered point.

Piles exceeding thirty (30) feet in length are shown as having additional reinforcing bars placed midway between the longer bars throughout the middle third length of the pile in order to provide for handling.

SPECIFICATIONS FOR DRIVING PRE-MOLDED CONCRETE PILES.

1. Piles shall be protected while being driven with an approved cushion cap.

2. The driving or jetting of piles shall be governed by "Pile Driving —Principles of Practice," given in the Specifications for Workmanship for Pile and Frame Trestles in the Manual of the Association.

3. In driving, a steam hammer shall be used unless otherwise specified by the Engineer. Where a drop hammer is permitted, a heavy hammer with a short drop shall be used.

4. Any pile injured in driving or driven out of place shall be either replaced by a new pile or pulled and re-driven, as the case may require.

5. On sloping ground, and where necessary, a suitable hole shall be dug at the location of each pile, sufficiently deep to hold the pile in proper position for the first few blows.

6. Before driving, the piles shall be carefully located and set to the line called for on the plan, and the pile driver leads held in proper position by means of guy lines. Unless otherwise called for on the plans, piles shall be driven as nearly as possible in a plumb position. Any pile out of plumb more than one-half inch per foot shall be pulled and re-driven if so required by the Engineer.

7. Reasonable efforts shall be made to drive the concrete piles to plan cut-off, the lengths of the piles having been determined by borings or test piles. Driving will be continued until this point is reached or until the following rate of penetration is secured, as specified by Engineer. (Cases where driving is through soft soil to hard bottom or rock excepted.)

8. Piles shall be driven to a point requiring the following minimum number of blows for the last two (2) inches of penetration of a single-action steam hammer (weight of plunger 5000 lbs., drop 36 in.), or hammer of like mechanical effect.

(a) When piles are to carry 18 net tons— 3 blows to last 2 inches.

(b) When piles are to carry 25 net tons— 4 blows to last 2 inches.

(c) When piles are to carry 50 net tons—10 blows to last 2 inches.

(d) When piles are to carry a load in excess of 50 tons, number of blows will be as specified by the Engineer.

9. When driving is interrupted before final penetration is reached record for degree of penetration shall not be taken until after at least two (2) inches of penetration has been obtained. When necessary to obtain the required penetration, piles may be driven not to exceed four (4) inches below plan cut-off.

CUTTING-OFF PILES.

1. Where it is not possible to drive concrete piles to plan cut-off, the portion of the pile above this point shall be removed, but, unless otherwise specified, a variation of four (4) inches will be allowed above the plan cut-off for the inequalities of the tops of the piles. All loose parts of the head of cut-off piles shall be removed. Where reinforcement has to be cut off, it shall be done by a hack saw or oxy-acetylene torch.

"MOLDED-IN-PLACE" PILES.

"Molded-in-place" piles may be divided into three general groups, according to their method of construction. The successive steps in each method are briefly enumerated below:

(a) A collapsible steel mandrel encased with a spirally reinforced sheet-steel casing is driven to the required penetration. The steel mandrel is then withdrawn and the steel casing which is left in the ground as a form, is filled with concrete.
(b) A cylindrical casing with a protecting point is driven to the required penetration. The casing after being filled with wet concrete is removed, and the space left by the casing is allowed to fill with concrete, thus forming the pile.
(c) A cylindrical casing with a core as a protecting and driving point is driven to the required penetration. The core is removed. A charge of concrete is placed and the core is used as a rammer to compress the surrounding soil at the base, thus forming an enlarged base to the pile.

Under conditions where "molded-in-place" piles may be used, the main advantages over the pre-molded piles are as follows:

(1) The length of the pile need not be definitely predetermined on account of being able to vary the lengths in driving.
(2) Saving in labor and material on account of the length of each pile being determined before concrete is placed, thus saving cut-offs.
(3) The delay resulting from allowing sufficient time for piles to season before they are handled is eliminated.
(4) Entire omission of reinforcement against handling.

The "molded-in-place" piles by the nature of their construction are essentially foundation piles, and may not in all cases be a substitute for the pre-molded piles.

In the use of "molded-in-place" piles it is necessary to consider the effects of vibration and soil movement due to the driving of adjacent piles. When the core of the pipe casing is driven for a given pile, it displaces and compresses the earth adjacent to the hole which is formed, and the elastic earth tends to relieve its stress by crowding back. Many rules have been formulated for driving these piles in order to protect the unseasoned concrete of piles previously placed. As the result of tests, each of the following rules have been adopted on various pieces of work:

(a) No concrete shall be deposited in any pile form until all driving is completed within a radius of 9 feet center to center of pile to be filled.

(b) The setting of the concrete in any pile must not, under any consideration, be disturbed by driving another pile or piles within a radius of less than 9 feet from it center to center, after a minimum interval of three hours or before the expiration of seven days from the time the concrete was mixed with water for that pile. The contractor may, however, at his own option drive pile forms within the 9-foot radius to a depth not more than 3 feet from the total estimated penetration inside of the 3-hour limit, and before the expiration of the seven-day limit, complete the driving of those forms.

The requirements necessary vary with the plans and the soil encountered. The unseasoned concrete is more liable to damage on account of the driving of piles when soil is made up of thin, hard strata alternating with soft strata.

The above rules for driving of adjacent piles have been neglected in many cases, on account of the expense incurred in their operation and the lack of definite knowledge as to their necessity.

It should also be added that the construction of molded-in-place pile requires more careful supervision to secure good results on account of the manner in which concrete is deposited, and the surrounding conditions which preclude inspection of the pile after the concrete is all in place.

All "molded-in-place" piles are patented and are generally driven by companies either owning or controlling the patented features. The diameter and shape of the piles vary: tapered piles average an 8-in. tip and an 18-in. top diameter for a pile 25 ft. in length. The uniform section piles are circular and average 17 in. in diameter. No general specifications can be made for their construction, as each type of pile has its individual features demanding special methods of construction.

The cost will vary from 85 cents to two dollars per linear foot, with an average cost of one dollar, depending upon the number of piles driven and their lengths. Lengths of piles are always measured from cut-off to tip of pile. The expense of moving and setting up the special equipment necessary for this type makes them more economical on larger rather than smaller pieces of work.

Loading of piles may be calculated from the same data as that given for pre-molded piles.

Appendix C.

TYPICAL DESIGN OF FOUNDATIONS FOR PIERS, ABUTMENTS, RETAINING WALLS AND ARCHES IN VARIOUS SOILS AND DEPTHS OF WATER (NOT INCLUDING PNEUMATIC FOUNDATIONS).

J. J. YATES, Chairman, Sub-Committee.

Your Committee has had this subject under consideration for three years.

The first year's work consisted in collecting information from the membership pertaining to preliminary investigation for foundations, bearing values of soils, and elements governing the design. The report of the year's work appears in Vol. 17, 1916, pp. 225-231 inclusive.

The second year's work consisted in collecting designs of important structures from the membership. A number of these designs, with explanatory notes, are published in Vol. 18, 1917, pp. 854-883.

Your Committee this year has confined its work to the examination of books, periodicals and papers relative to the design of foundations. About one hundred books and miscellaneous papers were examined, and a list of those giving interesting information on the subject is given as an addenda to this report.

No reliable information on the bearing power of soils has been collected and the Committee is of the opinion that nothing conclusive can be accomplished by a further consideration of the subject along these lines.

This subject has been under consideration for three years by a special committee of the American Society of Civil Engineers, which society has appropriated funds for carrying on the work. No conclusive report has yet been made by this committee. The difficulty is entirely in arriving at some definite classification of soils. If a satisfactory classification can be found, it will be a comparatively simple matter to make the tests and assign safe-bearing values to each class of soil.

The types of foundations are many and varied, depending on the purpose and character of the structure and the soil and conditions encountered, and the Comimttee feels this matter has been covered as far as practicable in the presentation of designs of important structures in last year's publications.

The methods and the apparatus used in making soil tests are very fully described in the publications given in the appendix.

There are a number of important elements entering into the design of foundations and on which the Committee has found a large divergence of opinion, and it is on these points your Committee presents the following as their opinion of best practice to be used in designing foundations:

(1) That for important structures wash borings as a means of determining character and bearing values of foundation soils are not generally reliable.

The most commonly known method of making wash borings is by means of a double pipe where the material is washed out by a stream of water through the center pipe as the outer pipe or casing is driven. Samples of the soil are obtained by catching at frequent intervals samples of the washings, and separating the sediment by settlement.

Another method quite commonly used where hard material is encountered is the percussion drill which pulverizes the materials it passes through. The pulverized material is either removed by a sand pump or washed out with a center pipe.

In either method the materials are thoroughly churned. Correct interpretation of the character of the soil by these methods is doubtful, depending as it does on observation of the speed of driving the casing and the drilling; furthermore, in the case of wash borings it is impracticable to distinguish solid rock from boulders.

That for important structures core borings give the most reliable data. The borings should in general be carried at least ten (10) feet into rock, when encountered.

Diamond, calyx or similar drills furnish cylindrical cores of all stratas of hard material. Soil, sand, clay and lighter materials will be brought to the surface similar to wash borings.

(2) That for important structures, where there is no reliable data, or where there is any question of the safe bearing value, soil bearing tests be made; the test loads being increased until settlement occurs or until twice the bearing load it is proposed to use in the design has been reached.

That one-half the ultimate load thus found be used in designing the foundation except that three-quarters (¾) of the ultimate load may be used for maximum toe pressures produced by tractive force or wind; provided, however, that the safe load thus found does not exceed the safe crushing value of the materials of the substructure.

By ultimate load is meant that load that can be placed on the soil without undue settlement. It is not intended to consider a slight compression of the soil from ¼ to ½-inch as settlement except in the case where the settlement is progressive under the load applied.

(3) That pile bearing formulas based on the fall and weight of the hammer are not always a true index of the safe bearing value of the pile, but are of value in determining the extent to which driving is necessary in a soil of known resistance.

Pile bearing formulas are not reliable in the case of the softer soils, where the carrying power is determined by the surface friction of the pile and there is a large increase in the supporting power of the pile after the driving ceases and the pile is allowed to remain unloaded for several hours, nor are they reliable in the case of piles driven through soft soil to rock or other hard material.

That for important structures where data is lacking or where there is any question of the safe bearing value, load tests be made; the loading being increased until settlement occurs or until twice the load per pile it is proposed to use in the design is reached.

That one-half the ultimate load thus found be used in designing the foundations except that three-quarters (¾) of the ultimate load may be used for the maximum pressures produced by tractive force and wind; provided, however, that the safe bearing value of the piling or materials of the substructure are not exceeded.

By ultimate load is meant that load that can be placed on the pile without undue settlement. It is not intended to consider a slight depression of the pile from ¼ to ½ inch, as settlement except in the case where the settlement is progressive under the load applied.

In arriving at the safe bearing value of piles consideration must be given to their action as columns taking into account the supporting action of the penetrated material.

(4) That in general buoyancy of structures in water be not considered as reducing the foundation load except in the case where water has free access to the base of the foundation or when calculating stability from overturning.

(5) That the loads to be considered in designing foundations are the total dead load of substructure and superstructure, the live load, including an allowance for impact, tractive force, wind and ice pressure, and earth pressures in the case of retaining walls and abutments.

(6) That in general the cut-off of wood foundation piles in tidal waters shall not be above mean daily tides and shall not exceed two (2) feet above mean low water.

That in general timber in foundations in tidal waters shall not be used above mean daily tides nor shall it be used at a greater elevation than two (2) feet above mean low water.

That in general wood foundation piling and timbers be kept entirely below the probable lowest ground water level, except in the case of tidal waters as above noted.

That in all waters where marine borers exist, no untreated timbers should be used above the permanent mud line of the bottom.

(7) That the spacing of wooden piling in foundations be not less than two (2) feet, six (6) inches, center to center.

(8) That the bottom of foundations should be placed entirely below the line of frost action, the depth of foundation depending on the locality.

(9) That the calculations of foundation pressures be made in accordance with the rules and formula for the design of retaining walls published in the Supplement to the Manual, Vol. 19, No. 197, pp. 47-55.

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Appendix D.

THE WISDOM OF THE USE OF BLAST FURNACE SLAG IN REINFORCED CONCRETE WORK, TAKING INTO ESPECIAL CONSIDERATION ITS PROBABLE DURATION.

W. S. LACHER, Chairman, Sub-Committee.

GENERAL.

Slags are defined in "Cement Limes and Plasters" by Eckel as "fusible silicates formed during the smelting or refining of metals by combination of the fluxing materials with the gangue of the ore. The composition of the slag, therefore, will be determined by the composition and relative proportions of the fluxes and the gangue." The slags of the iron and steel industry comprise those formed by the reduction of iron in a blast furnace and those resulting from the manufacture of steel. They are also sometimes differentiated to distinguish between those derived from the manufacture of Bessemer iron known as acid slags, and those resulting in the reduction of non-Bessemer ores known as basic slags.

The physical properties of slags are determined very largely by the methods used in cooling or disposal. This permits of division into three general classes: air cooled bank slag, granulated slag and machine slag. Granulated slag, the result of quenching with water, is a very light material, somewhat resembling sand, and has had but limited application as a concrete aggregate. Machine slag is not produced in sufficient quantities to be generally available.

The most common form of slag is that produced by dumping the molten slag from ladles into large spoil banks where it cools slowly by exposure to the air while being warmed by contact with preceding deposits and forms into a stone-like substance. It is removed for commercial utilization by a steam shovel, and when used like broken stone it is passed through a crusher and may be obtained in the gradations of size ordinarily available in stone.

From the above it is clear that the term "slag" includes materials of varying origin and widely differing physicial properties. A deposit of this material may contain only the relatively pure by-product of a single process, such as the reduction of iron in a blast furnace, or it may be composed of the conglomeration of materials from many processes, including the miscellaneous refuse of steel manufacture, obviously a mass of too indefinite a composition to be a trustworthy structural material. Consequently this discussion is limited to a slag having a sufficient market value as a by-product to justify production practices that will insure a uniform product free from foreign matter.

A further limitation is in the use of slag only as the *coarse* aggregate of the concrete, the fine aggregate being a natural sand conforming to the usual requirements for a fine aggregate. Tests of slag concretes in which the fine aggregate was a granulated or a finely crushed slag indicates its general inferiority as compared to sand of good quality.

Properties of Air-Cooled Blast Furnace Slag.

Air cooled slag has a generally dull gray color with varying degrees of porosity from that of pumice stone on one hand to a dense limestone on the other. It consists essentially of silica, alumina, iron oxide, and lime with or without magnesia. Sulphur is usually present in small quantities. The range of composition given by various authorities is as follows:

Silica	26.88 to 38.0 per cent
Alumina	10.0 to 28.0 per cent
Iron	0.44 to 0.75 per cent
Lime	29.0 to 50.0 per cent
Magnesia	1.0 to 18.50 per cent
Sulphur	trace to 4.90 per cent

In a report prepared by Sanford E. Thompson presented in abstract before the American Concrete Institute in February, 1917, he gives the range of usual composition as follows:

Silica	32.0 to 36.0 per cent
Alumina and Iron	11.0 to 15.0 per cent
Lime	40.0 to 48.0 per cent
Magnesia	1.0 to 7.0 per cent
Sulphur	1.1 to 1.7 per cent

He differentiates between magnesian slags in which the magnesia content is above 4 per cent. and limestone slags in which magnesia is present to less than 2 per cent.

Slag is usually appreciably lighter than stone. Specific gravity is not a reliable index on account of its porous nature. The weight per cubic foot of crushed slag varies from nearly 100 lbs. to less than 50 lbs. The concrete made with it also weighs less than stone or gravel concrete but usually not less than 135 lbs. per cu. ft.

Use.

The use of slag as an aggregate in concrete covers a period of 20 years or more but it is only within recent years that it has had extended use particularly in reinforced concrete. Beginning with its utilization for the concrete structures of the steel companies the greatest development has been in the communities tributary to the steel mills. Large quantities of slag are used in building operation, particularly in Birmingham, Cleveland and Youngstown, Ohio. The use of slag in concrete is sanctioned by the building ordinances of Detroit, Cleveland, Chicago, Philadelphia and Youngstown. Probably the most general use has been at Cleveland, where a large number of reinforced concrete buildings have been constructed with slag as a coarse aggregate

Specific examples of concrete structures in which slag is used include the grade separation structures of the Seaboard Air Line at Birmingham involving 11,000 cu. yds., the Rocky River Bridge at Rocky River, Ohio, subway structures of the Philadelphia Rapid Transit Company and the North Howard Street Bridge at Akron, Ohio. The last is an arch bridge nearly 800 ft. long with a roadway 190 ft. above the bed stream and required the use of 5,000 cu. yds, of concrete.

STRENGTH.

Numerous tests have been made of slag concrete which show conclusively that a properly selected slag when used as the coarse aggregate with a good quality of sand as the fine aggregate will produce a strong concrete.

These tests include the following:

Tests made by Sanford E. Thompson in connection with his investigation and reported before the American Concrete Institute in February, 1917.

Tests by Robert W. Hunt Company in September and November, 1908.

Tests at Cornell University reported in the Cornell Civil Engineer in 1913.

Tests at Columbia University, Department of Civil Engineering, January 1914.

Tests by Carnegie Steel Company in 1911.

Tests reported by W. A. Aiken, Proceedings of American Society for Testing Materials, 1914.

Five year tests by the Pittsburgh Testing Laboratories, now in progress.

These and other tests brought to notice in recent years go to show that slag concretes are as strong as stone or gravel concretes containing the same quantity of cement, provided a properly selected material is used. The strength bears little relation to the weight of the slag used, the porous varieties producing concretes of fully as great strength as the dense materials for tests at 28 days. For greater ages the concretes made of denser slags show a greater increase in strength. Owing to the fact that slag is generally more porous than stone it is necessary to exercise care in proportioning to provide sufficient mortar to fill the voids in the particles as well as between them.

SOUNDNESS.

A more important question is that of the soundness of slag concrete. This question is raised by the fact that some slags slake or disintegrate upon exposure to the air and are entirely unsuitable for use as aggregate. It is common practice to allow the slag to weather for a number of months before removing from the bank. This results in a hardening or toughening of the stable slags and permits the detection of those that disintegrate upon exposure to the atmosphere. A considerable difference of opinion and practice exists as to this seasoning, but good practice would seem to demand a period in the bank of six months to a year. However, it is a fact that some slags are used after only a few weeks' exposure with apparently satisfactory results.

The most discussed point in the use of slag as an aggregate in concrete arises from the presence of sulphur. It is contended that a lack of stability of the compounds of this element occurring would result in the eventual disintegration of the concrete and also that its presence would lead to the formation of sulphuric acid which would result in the corrosion of embedded steel. Sulphur usually occurs as a sulphide of calcium, a form in which it is inactive, but in the presence of water it is contended that sulphuric acid would result. On the other hand slag concrete has been used extensively in foundation work and numerous examples are cited of anchor bolts and other embedded pieces of iron and steel which have been in close contact with slag concrete containing sulphur for many years without any sign of injury.

The following quotation is taken from the report by Sanford E. Thompson:

On permanence: "As a result of a careful examination of various structures made with slag concrete and interviews with users of slag concrete, I find no evidence of disintegration where Portland cement was used. In certain cases with Puzzolan or slag cement, the concrete is not in first-class condition but this is to be expected with any Puzzolan cement concrete laid in air."

From "Summary": "No authentic cases of deterioration of slag concrete made of Portland cement or of rusting of steel embedded in such concrete have been discovered."

SLAG IN RAILWAY STRUCTURES.

With a view to securing some data on experience with slag in railway structures inquiry was made among railway engineers who have used slag in concrete, but owing to the limited application of this material to railroad structures as compared to office and industrial buildings, only a few replies containing information on the subject were obtained. These replies are given below:

New York Central Railroad, Lines West.

"We are now building the Himrod Ave. viaduct over our tracks at Youngstown. The structure is a steel affair with the lower parts completely enclosed in concrete. The Youngstown district is a bad one for obtaining first-class material for concrete. The sand is rather poor, and good first-class stone is not available. Some of the sand and gravel is obtained from the Ohio river, which is dirty and full of coal.

"There is hence every inducement to use slag on account of its cleanliness, uniformity of gradation, and comparatively low cost. The freight situation in this territory is congested, and it is hard to obtain other material on this account.

"Blast furnace slag has been used for a number of years in a small way. We have examined retaining walls that were built of slag at least eight years ago, and have found them in excellent condition. The Lorain Steel Company at Lorain, Ohio, has used this material quite extensively throughout its plant. At Warren, Ohio, a city reinforced concrete arch was built over the river, about two years ago. This structure seems to be in excellent shape.

"In view of the circumstances, we thought we were warranted in venturing somewhat into a new field. The viaduct proper is now about completed, and the concrete seems to be first class throughout."

(Signed) B. R. Leffler, Engineer of Bridges.

Erie Railroad.

"Concerning the behavior of blast furnace slag as an aggregate in plain and reinforced concrete, I attach herewith for your information, a report on the subject from our Inspecting Engineer, Mr. L. W. Walter, who is also in charge of our Cement Laboratory at Jersey City."

(Signed) R. S. Parsons, Assistant to the President and General Manager.

"Slag was used in several structures on the Erie Railroad in the years 1905, 1906 and 1907, and results compare favorably with structures built of other materials during the same period. We have more recently used slag in a few structures where its use has been of economic advantage. Such slag as we are now using in concrete work undergoes our inspection with a view of securing as dense a material as is available.

"I will offer as my opinion that there is room for slag producers to improve the quality of their average shipment by selecting and grading their material with a view of increasing the weight per unit of volume. We desire slag which will weigh 2000 lbs. yer yard, but are seldom able to secure slag weighing over 1900 lbs. per yard.

"Our experience with slag used on the Erie Railroad has been limited to plain concrete, but from observation elsewhere I have formed the opinion that slag in concrete does not cause corrosion of the metal reinforcement."

(Signed) L. W. Walter, Inspecting Engineer.

St. Louis-San Francisco Railway.

"Our use of slag for concrete has been limited to slag from the vicinity of Birmingham, Ala. I attach copy of a letter from District Engineer H. B. Barry, giving full report in regard to the use of this slag on our lines.

"In so far as we can tell up to this time, this slag has been giving very good results. The only question in regard to its use as I see the matter is whether or not there will be any chemical action in future which might affect the permanency of slag concrete. Our experience up to this time is insufficient tc pass on this question."

(Signed) V. K. Hendricks, Assistant Chief Engineer.

"Beginning with the spring of 1915, at which time the line between Memphis and Birmingham was added to my territory, we have used slag for coarse aggregate in concrete as follows:

1915 contract work	10,500 cu. yds.
1916 company force work	10,000 cu. yds.
1917 company force work	5,000 cu. yds.
Total	25,500 cu. yds.

"This material has been used in this work in a number of different kinds of structures, including concrete box culverts with reinforced tops; reinforced concrete wagon bridge on steel I-beams; plain concrete piers, and plain concrete abutments. The box culverts have varied in size from a 3x2 to a triple 16x16. The largest arch we have built is a 26x12. In all of these structures we have used steel furnace slag. The fine aggregate on the work was sand. All of these structures were mixed as per our standard plans and specifications. The arches, piers, and abutments are all of 1-3-6 mix and the box culverts of 1-2-½-5 mix.

"None of these structures has shown any signs of failure or deterioration. In finish and appearance these structures are as good as should be expected in ordinary railroad work. It is a little difficult for a green gang to properly spade slag concrete to give a good surface finish for, owing to the porous nature of the slag, it soaks up the thin mortar against the form, and unless a little extra spading is done, the faces of the structure will be left honeycombed. With a little experience and additional care, however, this difficulty can be entirely overcome.

"We have made a number of tests to determine compression strength of slag concrete, the samples being taken from the mixers on the job. Our samples 90 days old show an average strength of about 3000 lbs. per sq. in., and 30 days old have shown about 2000 lbs. per sq. in.

"The slag that is furnished us is all crushed, screened and washed. The material comes very well graded, maximum size passing through a 2-in. ring. The only difficulty we have had in getting this material furnished in proper shape is at times when the slag is run through the crusher and screens in rainy weather, under which conditions the dust and dirt is not properly screened out. This due to the poor facilities for washing and screening. The slag company, however, is building an up-to-date plant, which should be put in operation within the next few months, and it is their opinion that this new plant will properly screen and wash the slag in all kinds of weather.

"On the whole, it is my opinion that this slag is as good if not better for concrete work than the average limestone that we are able to buy. (Signed) H. B. Barry, District Engineer.

Southern Railway System, Lines West, Southern District.

"I beg to advise that we have used it in the construction of depot platform curbings and sidewalks, but to no great extent. The work in some instances stands up very well, but in others, where it receives considerable abuse, it fails under the service."

(Signed) R. D. Tobien, Engineer Maintenance.

Seaboard Air Line Railway Company.

"Yours of August 29th in regard to use of blast furnace slag in retaining walls of this road at Birmingham.

"The work has been entirely satisfactory to date, and beyond a few surface cracks or crazing, there are no signs of disintegration of any portion of the work." (Signed) W. D. Faucette, Chief Engineer.

Central of Georgia Railway Company.

"I have used slag in concrete for 20 years. I first used it when I was connected with the Carnegie Steel Company. I introduced its use on this road when I became Chief Engineer, about 11 years ago, and we have been using it to a large extent since that time, using it at all points on our line where it is cheaper than other aggregates. For heavy walls we have used considerable pit run, screening the dust only. For some time past, we have been using crushed slag.

"We have not used it as yet to any great extent in reinforced slab work, although I believe it will prove entirely satisfactory—in fact I know from other reports that it has been satisfactory. It was used almost entirely in connection with the Macon Station, and has proved entirely satisfactory. I have never known a failure, and we find that wherever we are obliged to cut into a wall of slag aggregate that it is harder than any other concrete. We have used it to a large extent in arches and in practically all kinds of concrete work, but the only work that I consider it inferior to stone is for street or road paving. Our experience is that it will not wear as evenly or as well as first-class quality of stone. I believe that in order to get the best results where much of the slag is honeycombed that it would be better to thoroughly mix the concrete dry in order to have the cement penetrate the voids before applying water."

(Signed) C. K. Lawrence, Chief Engineer.

The Wilkes-Barre Company.

"Your letter addressed to me at New York has been forwarded to me and I will endeavor to give you what information I can in regard to the results we obtained with the use of slag while I was connected with the Birmingham Railway, Light and Power Company.

"This company had been using slag for railway ballast for a number of years. Practically the first use of slag in building foundation work was on the construction of a foundation for a three million cubic foot gas holder.

"Our next use of slag was in the construction of several new buildings in which we used it for reinforced floors and 4 in. slab roofs with expanded metal. Most of this work, which was put in five or six years ago, is in as good condition as when first put in and does not show any sign of deterioration. We also used slag for the construction of lintels and coping for the various buildings and turned out some very good work.

"Prior to my connection with the Birmingham Railway, Light and Power Company, I had charge of the concrete work on the construction of the large coke oven plant. At that time, we put in over one hundred thousand yards of concrete and slag was used altogether as the coarse aggregate, and for all foundation work we used natural cement. In the reinforced floor work and tar and oil sumps, Portland cement was used in order to get a more impervious mixture. To make way for the new construction, it was necessary for us to tear down some old reinforced concrete work where slag had been used, that had been in for a number of years, and we found the steel work was in as good condition as when it was first put in.

"I was very much in favor of slag for use in concrete and would use it wherever it can be obtained, as every place we have used it we have secured excellent results."

(Signed) J. H. MacVeigh,
Formerly Engineer Birmingham Light Head & Traction Co.

SPECIFICATIONS.

The following specification for slag has been compiled:

Suggested by Sanford E. Thompson, based on his investigation.

"Slag must be air-cooled, crushed and screened from dust and free from foreign material. The weight of screened slag when shaken to refusal should not be less than 65 lb. per cu. ft.

"It is suggested that slag not falling within the limits of composition given be rejected."

General specifications for concrete and reinforced concrete by Jerome Cochran, 1913:

"Only best quality of hot pot slag free from dust and foreign matter shall be used. Slag shall be nearly free from sulphur and other injurious agents, and must be hard and not spongy. Slag a few months old is better and freer from sulphur.

"Crushed furnace slag conforming with the specifications for size and quality which will develop under a test a crushing and transverse strength equal to that of the stone herein specified, may be substituted. Should, however, the percentage of voids in the slag prove excessive a reduction in the proportion of slag may be made without additional compensation."

New York Central Lines West.

"Coarse and crushed slag may be used in concrete in place of crushed stone or gravel.

"The slag shall have the following properties:

"The slag shall weigh not less than 70 lb. per cu. ft. The lime shall not exceed 48 per cent. The sulphur compounds shall not exceed 1.7 per cent. No free sulphur will be allowed. The silica shall not be less than 33⅓ per cent.

"The contractor shall make a chemical analysis of every 2000 cu. yd. of material that is furnished. The Railroad Company shall be furnished with a copy of the analysis.

"The slag shall be air-cooled blast furnace product. It shall be cured for at least two months."

Central of Georgia Railway Company.

"The slag shall be crushed to the same size we would require in stone—to be free from dirt and dust. The only specification we require in addition to that covering stone is that the slag should season at least one year in the slag bank before being used."

Detroit-Superior Viaduct, County of Cuyahoga, Ohio.

Slag shall be of uniform texture with a minimum of cell holes, hard and reasonably free from foreign substance, which shall weigh not less than 2000 lb. per cu. yd.

Broken stones or slag used as a coarse aggregate shall have an abrasion loss of not more than 10, a factor of hardness of not less than 12, and a factor of toughness of not less than 6.

Building Department, City of Philadelphia.

Coarse aggregate shall consist of crushed stone, gravel, or slag. The particles shall be clean, hard, durable and free from all deleterious material.

All slag shall be clean, air-cooled blast furnace slag, weighing not less than 75 lb. per cu. ft. and containing not more than 1.3 per cent. of sulphur as sulphides.

Ohio State Highway Department.

General.

The broken slag shall be clean, sound, durable, reasonably uniform in density and quality and free from thin or elongated pieces.

	Grades		
	A	*B*	*C*
Chemical Composition.			
Silica (SiO_2)—not less than	32%	32%	32%
Calcium oxide (CaO)—not over	45%	45%	45%
Sulphur (S)—not over	1.5%	2%	2%
Physical Properties.			
Per cent. of wear (stone test)—not over	10%	15%	20%
Or, per cent. of wear (gravel test)—not over	20%	..	..
Toughness—not less than	5%	5%	..
Weight per cubic foot (as aggregate)—not less than	70 lb.	65 lb.	..

SUMMARY.

(1) The strength of concrete in which selected slag is used as the coarse aggregate is equal to that of a concrete made of stone if an equal amount of cement is used per volume of concrete.

(2) The extensive use of slag concrete over a period of years has demonstrated its permanence for buildings, retaining walls, bridges and foundations work where the structure is exposed to ordinary conditions.

(3) No data on water-tightness, or behavior when submerged, were obtained.

(4) No case has been brought to notice where embedded steel became corroded in a slag concrete.

(5) In general, slag concretes are superior to stone or gravel concretes where exposed to high temperatures.

(6) The user of slag for a concrete aggregate should satisfy himself as to suitability of the material tributary to his locality, from observation of the method of production and the service records of structures previously built.

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Appendix E.

DESIGNS AND RECOMMENDED SPECIFICATIONS FOR CONSTRUCTION OF CONCRETE CULVERT PIPE.

JOB TUTHILL, Chairman, Sub-Committee.

Plans and specifications of concrete pipe were obtained from all railroad companies known to have plans and specifications of their own, from firms manufacturing concrete pipe and from the Highway Departments of several states. The general features of these are outlined in Table I, and in the accompanying plans.

An analysis was made of several of the designs obtained, based upon developing 16,000 lbs. unit stress in the steel reinforcement, the results of which are shown in Table II.

The designs are of four types as to form and reinforcement:

1. Circular in cross-section with two concentric layers of reinforcement, one near the outside surface and the other near the inside surface of the pipe.
2. Circular in cross-section with one layer of reinforcement placed elliptically so as to pass continuously through all parts of the pipe that are subject to tension.
3. Oval in cross-section with one layer of circular reinforcement placed so as to pass continuously through all parts of the pipe that are subject to tension.
4. Circular in cross-section with one layer of concentric reinforcement.

As the points of greatest bending moments in the pipe are the segments crossed by the vertical and the horizontal diameters with the resulting tensile stress in the inner portion of the pipe for the vertical and in the outer portion for the horizontal moments, the fourth type of design does not provide reinforcement for the tensile stress from the horizontal moments and is, therefore, not recommended for use for culverts.

Pipes reinforced as in types No. 2 and No. 3 should have the top plainly marked in order that the pipe may be placed so that the reinforcement is in the proper position to carry the tensile stresses.

In designing reinforced concrete culvert pipe the use of unit stresses per square inch of 700 lbs. compression in the concrete and 16,000 lbs. tension in the steel may be considered good practice, and to develop these stresses approximately .88 per cent. of reinforcement is required.

NOTE.—Reference is made to a Bibliography on the manufacture and use of concrete pipe in Proceedings of American Railway Bridge and Building Association for 1915.

The following formulæ are proposed for the thickness of the pipe and the area of the reinforcement, in which:

t = distance in inches from the center of the reinforcement to the compression face of the concrete.
a = distance in inches from the center of the reinforcement to the tension face of the concrete.
$t^1 = t + a$ = total thickness of the pipe.
A = area of reinforcement in square inches.
d = mean diameter of the pipe in feet.
w = weight per square foot of the load on the pipe in pounds.
p = 0.83 per cent. of reinforcement.
fs = 16,000 lbs. = unit tensile stress in the reinforcement.
fc = 680 lbs. = unit compressive stress in the concrete.

(1) $t = 0.023d\sqrt{w}$ or
(2) $t = 0.03d\sqrt{w}$
(3) $A = 0.10t$
(4) $t^1 = t + a$

These formulæ are derived from those developed by Prof. A. N. Talbot from his experiments and tests of the strength of pipe published in Bulletin No. 22 of the Engineering Experiment Station of the University of Illinois, viz.:

$M = \frac{1}{16}wd^2$ for the value of the bending moment due to the load.
$MR = 0.87\ A\ fs\ t$ for the moment of resistance of the pipe.

The value (1), $t = 0.023d\sqrt{w}$, is obtained from the above bending moment $\frac{1}{16}wd^2$; the value (2), $t = 0.03d\sqrt{w}$, from the bending moment $1/10wd^2$.

The first is given by Prof. Talbot in the Bulletin and he has lately said:

"The moment coefficient 1/16 is the value derived for a load uniformly distributed horizontally over the width of the pipe and for a corresponding distribution of pressure below the pipe. To secure this condition the pipe must be unusually well bedded and there should be tamping on the sides of the pipe even although pressure from the sides would help to reduce the bending moment. If the pipe has not been bedded and filled in the best manner the bending moment developed in the pipe may be materially more than that used above. Committee C-6 of the American Society for Testing Materials selected the value 1/10Wd for the value of the bending moment for large drain tile laid in what is called ordinarily best practice. This is the value derived for a distribution of load over one-fourth of the circumference at the top of the pipe and a similar distribution of pressure below the pipe. It seems probable that moments at least as large as this may be expected to be developed in case only ordinary care is used in bedding the pipe and in filling. For this value of the bending moment, we have

$$t = 0.029d\sqrt{w}$$

It seems that .025 and .03 are as accurate as the conditions warrant. It is possible that .03 is not high enough for many conditions of bedding and filling."

In view of the possible lack of extreme care in bedding the pipe and in filling around it, the value of equation (2) for the value of "t" is recommended, viz.:

$$t = 0.03d\sqrt{w}$$

The load per square foot "w" will be the weight of the prism of earth above the pipe, the load from an engine and the load from impact. The weight of the earth will increase with the height of the fill while the load from the engine and from impact will decrease; the latter probably need not be considered except for low fills. It is evident also that the proportion of the weight of the prism of earth coming on the pipe decreases as the height increases. The Sub-Committee has given considerable study to the problem, to find a value for the load per square foot that would be sufficient for general use, but have been unable to find enough data to determine this satisfactorily.

The desirability of one value for all heights of fill under ordinary conditions is very evident, and we ask that further investigation be made for that purpose.

TABLE I—RAILWAY CULVERT PIPE.

Name of Railroad	Shape	Inside Diam.	Thickness	Length	Weight Lin.ft.	Steel Reinforcement			Curing	Brief Report of Failures
						No. of Layers	Longitudinal	Transverse		
Chicago, Rock Island & Pacific	Class B								Not less than forty-five (45) days	Several failures on new constructions due probably tp insufficient curing. No record of failures or breakages in handling.
	Oval	36"	4"	8'- 0"	600	One	12- 3/8" Sq. Rods	3/8" Sq. Rods @ 5"		
	Oval	48"	4"	8'- 0"	775	One	16- 3/8" " "	1/2" Sq. Rods @ 6"		
	Oval	60"	6"	6'- 0"	1630	One	20- 3/8" Sq. Rods	1/2" Sq. Rods @ 6"		
	Class C									
	Oval	36"	5½"	8'- 0"	950	One	12- 3/8" Sq. Rods	1/2" Sq. Rods @ 7"		
	Oval	48"	6½"	8'- 0"	1475	One	16- 3/8" Sq. Rods	1/2" Sq. Rods @ 6"		
	Oval	60"	7½"	5'- 0"	2280	One	20- 3/8" Sq. Rods	5/8" Sq. Rods @ 7½"		
	Class B									
	Circular	36"	4½"	8'- 0"	700	One	12-3/8" Sq. Rods	3/8" Sq. Rods @ 6"		
	Circular	48"	5-3/4"	8'- 0"	1125	One	16- 3/8" Sq. Rods	1/2" Sq. Rods @ 7"		
	Circular	60"	6-3/4"	7'- 0"	1665	One	20- 3/8" Sq. Rods	1/2" Sq. Rods @ 6"		
	Class C									
	Circular	36"	5-3/4"	8'- 0"	875	One	12-3/8" Sq. Rods	1/2" Sq. Rods @ 7"		
	Circular	48"	6-3/4"	8'- 0"	1375	One	16- 3/8" Sq. Rods	1/2" Sq. Rods @ 6"		
	Circular	60"	7-3/4"	5'- 6"	2070	One	20- 3/8" Sq. Rods	5/8" Sq. Rods @ 7½"		
Atchison, Topeka & Santa Fe	Class A								Thirty (30) Days of good drying weather	No Failures 1% Broken in handling while unloading.
	Circular	24"	4"	8'- 0"		Two	#208 A. S. & W. Co.'s Triang. Mesh			
	Circular	30"	4"	8'- 0"		Two	#267 A. S. & W. Co.'s Triang. Mesh			
	Circular	36"	4"	8'- 0"		Two	#395 A. S. & W. Co.'s Triang. Mesh			
	Circular	42"	4"	6'- 0"		Two	⅜" Rd. Corr. Rods @ 14"	½" Rd. Corr. Rods @ 5"		
	Circular	48"	4"	6'- 0"		Two	⅜" Rd. Corr. Rods @ 13"	½" Rd. Corr. Rods @ 4"		
	Class B									
	Oval	24"	3-1/2"	8'- 0"		One	#245 A. S. & W. Co.'s Triang. Mesh			
	Oval	30"	4"	8'- 0"		One	#267 A. S. & W. Co.'s Triang. Mesh			
	Oval	36"	4-1/2"	8'- 0"		One	#336 A. S. & W. Co.'s Triang. Mesh			
	Oval	42"	5"	6' -0"		One	#395 A. S. & W. Co.'s Triang. Mesh			
	Oval	48"	5-1/2"	6'- 0"		One	1/2" Rd.Corr. Rods @ 7"	1/2" Rd. Corr. Rods @ 5½"		
Atlantic Coast Line		24"	3"	Fixed by Chief Engineer		One	8- 3/8" Rd. Rods	1/4" Sq. Rods @ 2-3/4"	Seven (7)days above 60° Outside	
		30"	3-1/2"			One	12- 3/8" Rd. Rods	1/4" Sq. Rods @ 2-1/4"		
		36"	4"			One	16- 3/8" Rd. Rods	1/4" Sq. Rods @ 1-3/4"		
		42"	4"			One	20- 3/8" Rd. Rods	3/8" Sq. Rods @ 3-1/8"		
		48"	4-1/2"			One	24- 3/8" Rd. Rods	3/8" Sq. Rods @ 2-3/4"		
Chicago, Burlington & Quincy	Oval	12"	2-1/2"	4'- 0"	184	One	#5 A. S. & W. Co.'s Triangular Mesh		Ten (10) Days to Two (2) Weeks	One failure due to poor concrete Small number broken in handling.
	Oval	18"	3"	6'- 0"	277	One	#23 A. S. & W. Co.'s Triangular Mesh			
	Oval	24"	4"	8'- 0"	412	One	#23 A. S. & W. Co.'s Triangular Mesh			
	Oval	36"	4"	8'- 0"	600	One	#25 A. S. & W. Co.'s Triangular Mesh			
	Oval	48"	4"	8'- 0"	750	One	18 - 3/8" Rd. Corr. Rods	3/8" Rd. Corr. Rods @ 3		
	Oval	60"	6"	6'- 0"	1600	One	18- 1/2" Rd. Corr. Rods	1/2" Rd. Corr. Rods @ 4½"		
	Oval	72"	7"	6'- 0"	2350	One	22- 1/2" Rd. Corr. Rods	1/2" Rd. Corr. Rods @ 4"		
Chicago, Milwaukee & St. Paul	Circular	20"	4"	6'- 0"	310	One	6- 3/8" Rd. Rods	1/4" Sq. Rods @ 3-3/4"	Twenty (20)days Summer. Thirty (30)days Winter.	Failures due to insufficient curing or movements of Fill. No Breakage in handling.
	Circular	24"	4-1/2"	6'- 0"	395	One	4- 1/4" Φ & 4- 3/8" Φ	3/8" Rd. Rods @ 5"		
	Circular	32"	5-1/2"	6'- 0"	620	One	4- 1/4" Φ & 4- 3/8" Φ	3/8" Rd. Rods @ 3-3/4"		
	Circular	36"	4-1/2"	6'- 0"	567	Two	6- 1/4" Φ & 6- 3/8" Φ	3/8" Rd. Rods @ 3-1/2"		
	Circular	42"	6"	6'- 0"	750	Two	8- 1/4" Φ & 6- 3/8" Φ	3/8" Rd. Rods @ 2-1/2"		
	Circular	48"	5-1/2"	6'- 0"	933	Two	8- 1/4" Φ & 8- 3/8" Φ	3/8" Rd. Rods @ 2-1/2"		

TABLE I.—RAILWAY CULVERT PIPE.

Name of Railroad	Shape	Inside Diam.	Thick-ness	Length	Weight Lin.ft.	Steel Reinforcement			Curing	Brief Report of Failures
						No. of Layers	Longitudinal	Transverse		
Grand Trunk	Oval	18"	2-1/2"	8'- 3"	190	One	6- 3/8" Rd. Rods	#24 A.S.& W.Co. Tri. Mesh	Not to be shipped until (30) thirty days after casting. Not to be fully loaded until (45) forty-five days after casting.	
	Oval	20"	2-3/4"	8'- 3"	233	One	6- 3/8" Rd. Rods	#24 A.S.& W.Co. Tri. Mesh		
	Oval	24"	3"	8'- 3"	300	One	8- 3/8" Rd. Rods	#23 A.S.& W.Co. Tri. Mesh		
	Oval	30"	3-1/2"	8'- 3"	435	One	10 - 3/8" Rd. Rods	1/4" Sq. Rods @ 3-1/2"		
	Oval	36"	4"	8'- 3"	590	One	14- 3/8" Rd. Rods	1/4" Sq. Rods @ 3"		
	Oval	42"	4"	8'- 3"	675	One	18- 3/8" Rd. Rods	3/8" Rd. Rods @ 4"		
	Oval	48"	4-1/4"	8'- 3"	815	One	20- 3/8" Rd. Rods	3/8" Rd. Rods @ 3"		
	Oval	54"	6"	6'- 4"	1075	One	22- 3/8" Rd. Rods	3/8" Sq. Rods @ 4"		
	Oval	60"	5"	6'- 4"	1200	One	14 - 1/2" Sq. Rods	1/2" Sq. Rods @ 6¼"		
	Oval	68"	6"	6'- 4"	1700	One	18 - 1/2" Sq. Rods	1/2" Sq. Rods @ 5-3/4"		
	Oval	84	7"	6'- 4"	2445	One	26- 1/2" Sq. Rods	1/2" Sq. Rods @ 4-1/2"		
Great Northern	Bell-								About thirty (30) days.	Used since 1911. No record of failures in Service. Small percentage of pipe broken in handling.
	Oval	18"	3"	8'- 0"	262	One	4- 3/8" D'f'd. Sq.Rods	#23 A.S.& W.Co. Tri.Mesh		
	Oval	24"	4"	8'- 0"	438	One	6- 3/8" D'f'd. Sq.Rods	#23 A.S.& W.Co. Tri. Mesh		
	Oval	30"	4"	8'- 0"	525	One	8- 3/8" D'f'd. Sq.Rods	#23 A.S.& W.Co. Tri. Mesh		
	Oval	36"	4"	8'- 0"	612	One	8- 3/8" D'f'd. Sq.Rods	3/8" Sq. Rods @ 5"		
	Oval	42"	4"	8'- 0"	688	One	10-3/8" D'f'd. Sq.Rods	3/8" Sq. Rods @ 3-7/8"		
	Oval	48"	4-1/2"	6'- 0"	933	One	12-3/8" D'f'd. Sq.Rods	3/8" Sq. Rods @ 3-1/4"		
	Oval	60"	6"	6'- 0"	1633	One	16-3/8" D'f'd. Sq.Rods	1/2" Sq. Rods @ 4-1/2"		
	Sleeve									
	Oval	18"	3"	8'- 0"	220	One	4- 3/8" D'f'd. Sq.Rods	#23 A.S.& W.Co. Tri. Mesh		
	Oval	24"	4"	8'- 0"	382	One	6- 3/8" D'f'd. Sq.Rods	#23 A.S.& W.Co. Tri. Mesh		
	Oval	30"	4"	8'- 0"	460	One	6- 3/8" D'f'd. Sq.Rods	#23 A.S.& W.Co. Tri. Mesh		
	Oval	36"	4"	8'- 0"	538	One	8- 3/8" D'f'd. Sq.Rdos	3/8" Sq. Rods @ 5"		
	Oval	42"	4"	8'- 0"	612	One	12-3/8" D'f'd. Sq.Rods	3/8" Sq. Rods @ 3-7/8"		
	Oval	48"	4-1/2"	6'-0"	767	One	12-3/8" D'f'd. Sq.Rods	3/8" Sq. Rods @ 3-1/4"		
	Oval	60"	6"	6'- 0"	1313	One	16-3/8" D'f'd. Sq.Rods	1/2" Sq. Rods @ 4-1/2"		
Illinois Central	Circular	30"	4"			One	1/3" Sq. Corr. Rods @9"	1/3" Sq.Corr. Bars @ 3"	Thirty (30) days.	Used since 1910. 1910-1915 put 28,000 lin.ft. into service. No record of failures. Small percent broken in handling.
	Circular	36"	4"			One	1/3" Sq. Corr.Rods @ 9"	1/3" Sq. Corr. Rods @ 3"		
	Circular	42"	4"			One	1/3" Sq. Corr.Rods @ 9"	1/3" Sq. Corr. Rods @ 3"		
	Circular	48"	4-1/2"			One	1/3" Sq. Corr.Rods @ 9"	1/3" Sq. Corr. Rods @ 3"		
	Circular	60"	5"			One	3/8" Sq. Corr.Rods @ 9"	3/8" Sq. Corr. Rods @ 3"		
	Circular	30"	4"			Two	1/3" Sq. Corr.Rods @ 9"	1/3" Sq. Corr. Rods @ 3"		
	Circular	36"	4"			Two	1/3" Sq. Corr.Rods @ 9"	1/3" Sq. Corr. Rods @ 3"		
	Circular	42"	4"			Two	1/3" Sq. Corr.Rods @ 9"	1/3" Sq. Corr. Rods @ 3"		
	Circular	48"	4-1/2"			Two	1/3" Sq. Corr.Rods @ 9"	1/3" Sq. Corr. Rods @ 3"		
	Circular	60"	5"			Two	3/8" Sq. Corr.Rods @ 9"	3/8" Rd. Corr. Rods @ 3"		
Kansas City & Southern	Circular	24"	4"	4'- 0"	450#	Two			Thirty (30) days	Used since 1909. Some failures due to faulty material. Breakage in handling rare.
						Outside	5- 1/4" Corr. Rods	1/4" Corr. Rods @ 6"		
						Inside	5- 1/4" Corr. Rods	1/4" Corr. Rods @ 6"		
	Circular	30"	5"	8'- 0"	670#	Outside	6- 1/4" Corr. Rods	1/4" Corr. Rods @ 6"		
						Inside	6- 1/4" Corr. Rods	1/4" Corr. Rods @ 6"		
	Circular	36"	5"	8'- 0"	780#	Outside	8- 1/4" Corr. Rods	1/4" Corr. Rods @ 6"		
						Inside	8- 1/4" Corr. Rods	1/4" Corr. Rods @ 6"		
	Circular	48"	5"	8'- 0"	980#	Outside	11- 1/4" Corr. Rods	1/4" Corr. Rods @ 6"		
						Inside	11- 1/4" Corr. Rods	1/4" Corr. Rods @ 6"		

Name of Railroad	Shape	Inside Diam.	Thickness	Length	Weight Lin.ft.	Steel Reinforcement			Curing	Brief Report of Failures
						No. of Layers	Longitudinal	Transverse		
Kansas City & Southern	Circular	60"	5"	5'-0"		Outisde	13- ¼" Corr. Rods	1/4" Corr. Rods @ 5"		
						Inside	13- 1/4" Corr. Rods	1/4" Corr. Rods @ 5"		
	Circular	72"	6"	5'- 0"		Outside	15- 1/4" Corr. Rods	3/8" Corr. Rods @ 9"		
						Inside	15- 1/4" Corr. Rods	3/8" Corr. Rods @ 9"		
Michigan Central	Circular	24"	4"	6'- 4"		Two	8- 1/4" Sq. Rods	1/4" Sq. Rods @ 3"	Forms in place 72 hours Not to be handled until after 3 weeks.	No failure up to 1915. Few cracked in handling due to carelessness.
	Circular	30"	4"	6'- 4"		Two	10- 3/8" Sq. Rods	3/8" Sq. Rods @ 5"		
	Circular	36"	4-1/4"	6'- 4"		Two	10- 3/8" Sq. Rods	3/8" Sq. Rods @ 4"		
	Circular	42"	4-3/4"	6'- 4"		Two	12- 3/8" Sq. Rods	3/8" Sq. Rods @ 3-1/2"		
	Circular	48"	5-1/4"	6'- 4"		Two	14- 1/2" Sq. Rods	1/2" Sq. Rods @ 5-3/4"		
	Circular	60"	6-1/4"	5'- 4"		Two	18- 1/2" Sq. Rods	1/2" Sq. Rods @ 5"		
	Circular	72"	7-1/4"	5'- 4"		Two	22- 1/2" Sq. Rods	1/2" Sq. Rods @ 4"		
Minneapolis, St. Paul & Sault Ste. Marie	Circular	12"	2"	5'- 4"	110#	One	6- 3/8" Rd. Rods	#4 A.S.& W.Co. Tri. Mesh	Thirty (30) days at temp. 70° to 120°. 4 days in moist air at temp. 70° to 100°.	No failures recorded. Very little breakage in handling.
	Oval	18"	2-1/2"	8'- 3"	190	One	6- 3/8" Rd. Rods	#23 A.S.& W.Co. Tri. Mesh		
	Oval	20"	2-3/4"	8'- 3"	233	One	6- 3/8" Rd. Rods	#23 A.S.& W.CO. Tri. Mesh		
	Oval	24"	3"	8'- 3"	300	One	8- 3/8" Rd. Rods	#23 A.S.& W.Co. Tri. Mesh		
	Oval	30"	3-1/2"	8'- 3"	435	One	10- 3/8" Rd. Rods	3/8" Rd. Rods @ 3-3/4"		
	Oval	36"	4"	8'- 3"	590	One	12- 3/8" Rd. Rods	3/8" Rd. Rods @ 3-3/4"		
	Oval	42"	4"	8'- 3"	675	One	14- 3/8" Rd. Rods	3/8" Rd. Rods @ 2-7/8"		
	Oval	48"	4-1/4"	8'- 3"	815	One	18- 3/8" Rd. Rods	1/2" Sq. Rods @ 6"		
	Oval	60"	5"	6'- 4"	1200	One	16- 1/2" Sq. Rods	1/2" Sq. Rods @ 6"		
	Oval	68"	6"	6'- 4"	1700	One	16- 1/2" Sq. Rods	1/2" Sq. Rods @ 3"		
	Oval	84"	7"	6'- 5"	2000	One	16- 1/2" Sq. Rods			
Northern Pacific	Oval	24"	4"	8'- 0"		One	8- 3/8" Rd. Corr. Rods	#23 A.S.& W.CO. Tri. Mesh	Sixty (60) days.	No failures due to poor construction. Small breakage record.
	Oval	36"	4"	8'- 0		One	10- 3/8" Rd. Corr. Rods	#23 A.S.& W.Co. Tri. Mesh		
	Oval	48"	4"	8'- 0"		One	18- 1/3" Sq. Corr. Rods	1/3" Sq. Corr. Rods @ 3"		
Wabash	Circular	24"	4"	8'- 4"	396	Two	6- 1/4" Rd. Rods	3/8" Rd. Rods @ 6"		
	Circular	30"	4"	8'- 4"	479	Two	6- 1/4" Rd. Rods	1/2" Rd. Rods @ 6"		
	Circular	36"	4"	8'- 4"	560	Two	6- 1/4" Rd. Rods	1/2" Rd. Rods @ 6"		
	Circular	48"	4-1/2"	6'- 4"	857	Two	8- 1/4" Rd. Rods	5/8" Rd. Rods @ 6"		
	Circular	60"	5"	6'- 4"	1183	Two	8- 1/4" Rd. Rods	5/8" Rd. Rods @ 6"		

TABLE II.

RAILROAD A.

Size Pipe	Mean Diam.	t	A sq. in.		p	j	For fs = 16000		
							w^1	w^2	fc
18"	1.75'	2.00"	.170	.085t	.0071	.878	2400	1500	620
24"	2.33'	3.00"	.170	.057t	.0048	.896	1800	1125	490
36"	3.33'	3.00"	.338	.113t	.0094	.864	1690	1060	740
42"	3.83'	3.00"	.423	.141t	.0165	.851	1590	1000	850
48"	4.38'	3.50"	.520	.149t	.0124	.850	1730	1080	880
60"	5.50'	4.75"	.667	.140t	.0117	.860	1920	1200	889

RAILROAD B.

Size Pipe	Mean Diam.	t	A sq. in.		p	j	w^1	w^2	fc
24"	2.25'	2.50"	.250	.10t	.0083	.87	2280	1425	680
30"	2.83'	3.50"	.338	.097t	.0081	.872	2750	1720	675
36"	3.36'	3.75"	.423	.113t	.0094	.864	2500	1610	740
42"	3.90'	4.00"	.485	.121t	.0101	.861	2340	1460	780
48"	4.45'	4.50"	.500	.111t	.0093	.866	2100	1310	735
60"	5.52'	4.75"	.600	.126t	.0105	.859	1720	1075	795
72"	6.60'	6.25"	.750	.120t	.0100	.861	1980	1240	770

RAILROAD C.

Size Pipe	Mean Diam.	t	A sq. in.		p	j	w^1	w^2	fc
24"	2.33'	3.00"	.116	.039t	.0033	.896	1240	775	334
30"	2.92'	4.00"	.116	.029t	.0024	.908	1060	660	280
36"	3.42'	4.00"	.125	.031t	.0026	.906	820	510	294
48"	4.42'	4.00"	.131	.033t	.0027	.901	520	325	300
60"	5.42'	4.00"	.150	.038t	.0032	.897	400	250	330
72"	6.50'	5.00"	.148	.030t	.0025	.907	340	212	290

RAILROAD D.

Class "A" (Circular)

Size Pipe	Mean Diam.	t	A sq. in.		p	j	w^1	w^2	fc
24"	2.33'	3.00"	.208	.069t	.0058	.89	2200	1370	560
30"	2.83'	3.00"	.267	.089t	.0074	.88	1870	1180	660
36"	3.33'	3.00"	.470	.157t	.0131	.85	2300	1440	930
42"	3.83'	3.00"	.470	.157t	.0131	.85	1740	1080	930
48"	4.33'	3.00"	.588	.196t	.0163	.84	1690	1050	1090

Class "B" (Elliptical)

Size Pipe	Mean Diam.	t	A sq. in.		p	j	w^1	w^2	fc
24"	2.29'	2.50"	.245	.098t	.0082	.87	2180	1360	670
30"	2.83'	3.00"	.267	.089t	.0074	.88	1940	1165	660
36"	3.38'	3.50"	.336	.096t	.0080	.87	1910	1190	660
42"	3.92'	4.00"	.362	.091t	.0076	.88	1780	1110	670
48"	4.46'	4.50"	.428	.095t	.0079	.87	1800	1120	650

IOWA HIGHWAY COMMISSION—Standard Pipe.

Size Pipe	Mean Diam.	t	A sq. in.		p	j	w^1	w^2	fc
15"	1.44'	1.50"	.058	.040t	.0033	.91	850	510	395
18"	1.71'	1.75"	.077	.045t	.0038	.91	900	560	445
24"	2.25'	2.25"	.102	.045t	.0038	.91	880	550	445
30"	2.80'	2.75"	.151	.054t	.0045	.90	1000	630	480
36"	3.33'	3.25"	.170	.052t	.0043	.90	950	600	460
42"	3.88'	3.75"	.225	.060t	.0050	.89	1060	670	600

IDAHO HIGHWAY COMMISSION.

Size Pipe	Mean Diam.	t	A sq. in.		p	j	w^1	w^2	fc
12"	1.17'	1.25"	.000	.000	.0000	.00	000	000	000
18"	1.71'	1.75"	.041	.023t	.0019	.93	480	300	000
24"	2.23'	2.00"	.077	.038t	.0032	.91	600	370	000
30"	2.75'	2.25"	.110	.049t	.0041	.90	640	400	000
36"	3.27'	2.50"	.151	.060t	.0050	.89	670	416	000

NOTE: The value w^1 is obtained from the moment $M = \frac{1}{16}wd^2$; w^2 from $M = 1/10wr^2$.

TABLE II—CONTINUED.

Size Pipe	Mean Diam.	t	A sq. in.		p	j	For fs = 16000		
							w^1	w^2	fc
				MINNESOTA HIGHWAY COMMISSION.					
12"	1.17′	1.25"	.083	.067t	.0056	.89	1450	900	540
18"	1.71′	1.75"	.083	.048t	.0040	.90	990	620	430
24"	2.25′	2.25"	.083	.037t	.0031	.91	720	450	370
30"	2.80′	2.50"	.147	.059t	.0049	.89	910	570	480
36"	3.33′	2.75"	.147	.054t	.0045	.90	710	440	480
				RAILROAD E.					
20"x18"	1.71′	1.87"	.102	.054t	.0045	.90	1240	780	485
23"x20"	1.90′	2.12"	.170	.080t	.0067	.88	1880	1180	595
27"x24"	2.25′	2.25"	.170	.076t	.0063	.88	1420	890	560
33"x30"	2.79′	2.62"	.170	.065t	.0054	.89	1080	680	525
40"x36"	3.33′	3.00"	.354	.118t	.0098	.86	1740	1090	750
46"x42"	3.83′	3.00"	.356	.119t	.0099	.86	1350	840	755
52"x48"	4.36′	3.12"	.450	.144t	.0120	.85	1330	830	855
65"x60"	5.42′	3.75"	.500	.134t	.0111	.86	1170	730	850
74"x68"	6.17′	4.50"	.500	.111t	.0093	.87	1100	688	760

SPECIFICATIONS FOR THE CONSTRUCTION OF REINFORCED CONCRETE CULVERT PIPE.

CONCRETE MATERIAL.

Cement.

1. The cement shall be Portland and shall meet the requirements of the Standard Specifications for Portland cement of the American Railway Engineering Association. Cement that has deteriorated or become damaged during transportation or storage shall not be used.

Fine Aggregate.

2. The fine aggregate shall consist of sand or crushed stone, graded from fine to coarse, and passing when dry a screen having four (4) meshes per linear inch. It shall preferably be of hard silicious material, clean, coarse and free from dust, soft particles, loam and vegeable or other foreign matter.

Not more than twenty (20) per cent. shall pass a sieve having fifty (50) meshes per linear inch and not more than six (6) per cent. shall pass a sieve having one hundred (100) meshes per linear inch.

Coarse Aggregate.

3. The coarse aggregate shall consist of crushed stone or gravel which is retained on a screen having four (4) meshes per linear inch and shall not exceed three-quarters (¾) of an inch in greatest dimension for pipe four and one-half (4½) inches or less in thickness, or one (1) inch in greatest dimension for pipe of thickness greater than four and one-half (4½) inches. The coarse aggregate shall be a gradation of sizes from the smallest to the largest particles, and shall be clean, hard, durable and free from all deleterious matter. Aggregates containing dust, soft or elongated particles shall not be used.

Water.

4. The water used shall be free from oil, acid, alkali and vegetable matter.

STEEL REINFORCEMENT.

5. The steel for reinforcement shall meet the requirements of the Standard Specifications for Steel Reinforcement of the American Railway Engineering Association.

WORKMANSHIP.

Proportions.

6. The proportions of the materials for the concrete shall be:

One (1) part Portland cement.
Two (2) parts fine aggregate.
Four (4) parts coarse aggregate.

Measurement.

7. The unit of measure shall be a cubic foot. A bag containing not less than ninety-four (94) lbs. of cement shall be assumed to measure one cubic foot of cement. The fine and coarse aggregate shall be measured as loosely thrown into the measuring receptacle. The various ingredients, including the water, shall be measured separately, and by such methods as to invariably secure the proper proportions.

Mixing.

8. The concrete materials shall be mixed to the desired consistency in a batch mixer of an approved type. The mixing shall continue for at least two (2) minutes after all the materials, including the water, are in the mixer.

Consistency.

9. Sufficient water shall be used to produce a concrete of such consistency that it will flow around the reinforcement, but not enough to allow the coarse aggregate to separate from the mortar.

Retempering.

10. Retempering of mortar or concrete, that is, remixing with water after it has partially set, will not be permitted.

Placing Concrete.

11. The concrete shall be placed in layers so as to completely fill the entire space between the inner and the outer forms in one continuous operation; and shall be well spaded and compacted around the reinforcing metal, to obtain a concrete of maximum density, thoroughly bonded with the reinforcement, and smooth, dense watertight surfaces inside and outside of the pipe.

Temperature.

12. No pipe shall be manufactured in a temperature below forty (40) degrees Fahrenheit. Both aggregates shall be heated if necessary to remove frost and frozen lumps.

Forms.

13. The forms shall be steel or metal-lined, true to plan, substantial and unyielding. They shall be kept free from rust, carefully cleaned of all adhering concrete after each use, and well oiled or greased each time before the concrete is placed.

DESIGN.

Classes.

14. Reinforced concrete culvert shall be of the following classes or forms:

A—Circular in cross-section with two (2) concentric layers of reinforcement.

B—Circular in cross-section with one (1) layer of reinforcement placed elliptically.

C—Oval in cross-section with one (1) circular layer of reinforcement.

In all classes the location of the reinforcement shall be so designed that it will receive and carry the tensile stresses.

Thickness and Area Reinforcement.

15. The thickness of the pipe and the area of the reinforcement shall be based upon unit stresses of seven hundred (700) lbs. per square inch compression in the concrete and sixteen thousand (16,000) lbs. per square inch tension in the steel and 0.83 per cent. of reinforcement, and shall be determined by the following formulae:

$$t^1 = t + a$$

$$t = 0.03d\sqrt{w}$$

$$A = 0.10t$$

In which: t^1 = total thickness of the pipe in inches

d = mean diameter of the pipe in feet

w = load per square foot on the pipe in pounds

a = distance from the center of the reinforcement to the tension face of the concrete.

t = distance from the center of the reinforcement to the compression face of the concrete.

A = area of the reinforcement in square inches.

"a" shall not be less than three-quarters (¾) of an inch for pipe less than four (4) inches thick, and not less than one (1) inch for pipe of thickness greater than four (4) inches.

"w" shall be the weight of the earth fill, assumed at one hundred and thirty (130) lbs. per cubic foot to which shall be added for the engine load an amount obtained by dividing four thousand five hundred (4500) lbs. by one plus one-half the height of the fill above the pipe in feet. In no case shall "w" be less than two thousand (2000) lbs.

DETAILS OF CONSTRUCTION.

Reinforcement.

16. The reinforcement shall consist of transverse and longitudinal rods of the size and spacing required by the design; or of triangular

wire mesh or similar wire mesh of the size and weight required. The transverse and longitudinal rods shall be securely wired together at their intersections with No. 16 gage soft steel wire.

When two (2) layers of reinforcement are used they shall be connected together at proper intervals by tie struts so arranged that the two (2) layers may be handled as one member.

The reinforcement shall be thoroughly cleaned of all rust and scales, accurately placed and rigidly secured against displacement during the placing of the concrete.

Splicing Reinforcement.

17. All splices shall be made at points of minimum stress. The splices in wire mesh shall lap at least two spaces or not less than eight (8) inches. Rods shall lap not less than twenty-four (24) diameters and the laps shall be tightly wired with No. 16 gage soft steel wire.

Joints.

18. The joints shall be of the bell and spigot type. Where the thickness of the pipe is sufficient the bell may have the same external diameter as the body of the pipe; where the thickness is not sufficient to permit this the end of the pipe shall be flared out to form the bell.

The reinforcement shall be extended into the bell and bent to its form; with rod reinforcement two (2) transverse rods shall be placed in the bell and the longitudinal rods, bent if necessary to the form of the bell, shall be securely wired to these transverse rods.

The top of pipe with reinforcement placed as in Classes "B" and "C" shall be marked on both ends with the word "Top" in order to insure the proper placing of the pipe.

Finish.

19. All pipe shall have a clean, smooth finish both inside and outside. All smoothing, trimming or cleaning shall be done immediately after the forms are removed.

Curing.

20. The forms shall not be removed until the concrete has thoroughly hardened and will not be injured or the pipe deformed in handling; and in no event in less than twenty-four (24) hours after the concrete is placed.

The pipe shall be kept moist by frequent sprinkling with water for not less than seven (7) days, sheltered from the sun during hot weather, and allowed to cure for twenty-eight (28) days before shipping; and shall not be subject to full loading in less than forty-five (45) days after casting.

PATENTS.

21. The contractor or manufacturer shall pay all royalties for the use of patented designs or devices or forms of construction, and shall

protect the Railroad Company from all claims of infringements or liability for the use of such patents.

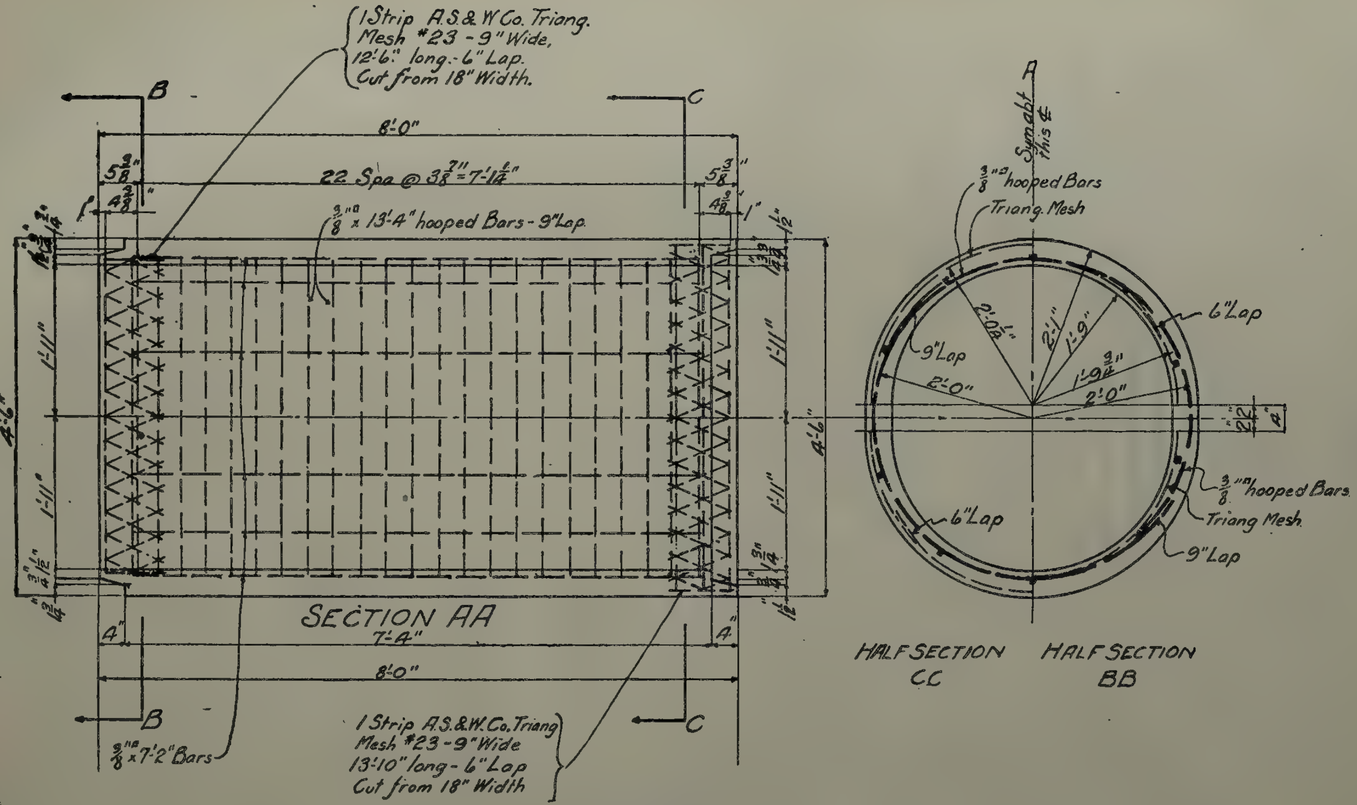
INSPECTION.

22. All material and all processes of manufacture shall be subject to inspection and approval at all times. Free access shall be provided for all authorized inspectors to all parts of factories and plants in which the pipe or the materials for the same are made or prepared.

All facilities for the desired inspection of materials and workmanship shall be furnished free of charge by the contractor as requested. In general the cement and reinforcing material will be inspected at the factory or mill. The aggregates and process of manufacture will be inspected at the pipe plant.

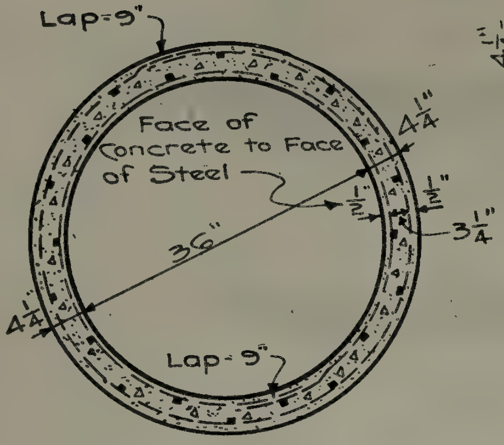
At the time the forms are removed the inspector shall carefully examine each piece of pipe and shall stamp or print the date of manufacture on the bell end of each pipe accepted.

Pipe that is injured or develops imperfections while stored at the manufacturer's plant will be rejected, notwithstanding the inspector's previous acceptance. No defective pipe shall be loaded for shipment. All pipe shall be so loaded and braced that they will not be broken in transit.

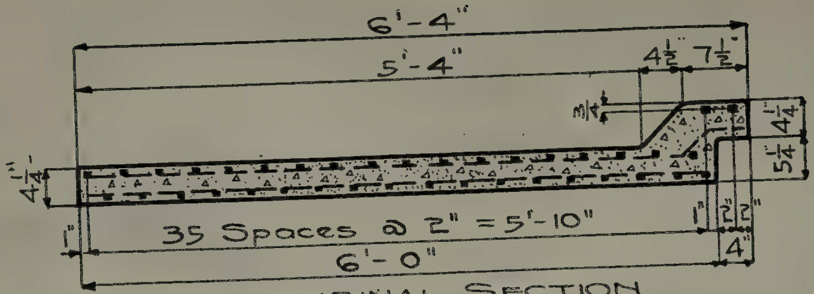

1 Strip A.S.& W Co. Triang. Mesh #23 - 9" Wide, 12'6" long - 6" Lap. Cut from 18" Width.
B
C
8'-0"
5 3/8"
22 Spa @ 3 7/8" = 7'-1 1/4"
4 3/8"
1"
3/8" x 13'-4" hooped Bars - 9" Lap.
1'-11"
4'-6"
SECTION AA
7'-4"
4"
8'-0"
3/8" x 7'-2" Bars
1 Strip A.S.&W. Co. Triang Mesh #23 - 9" Wide 13'-10" long - 6" Lap Cut from 18" Width
A
Symabt this ℄
3/8" hooped Bars
Triang. Mesh
2'-0 1/8"
2'-1"
1'-9"
1'-9 3/4"
2'-0"
9" Lap
6" Lap
HALF SECTION CC
HALF SECTION BB

GREAT NORTHERN RAILWAY.

42-INCH REINFORCED CONCRETE PIPE, WITH SLEEVE JOINT.



CROSS SECTION



LONGITUDINAL SECTION

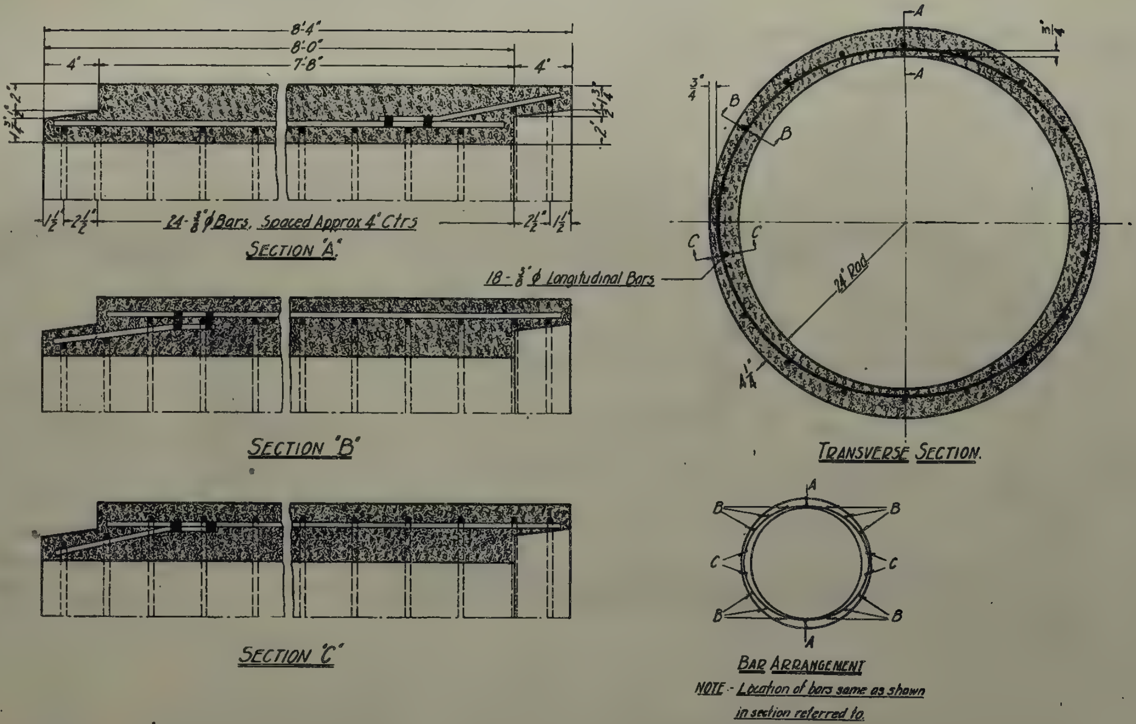
All Rods $\frac{3}{8}$" ϕ

Longitudinal and Transverse bars shall be securely wired together at their intersections with # 16 iron wire. At splices the bars shall be lapped not less than 9" and the laps tightly wired with 20 turns of #16 iron wire

M.C.R.R.

STANDARD

36" CONCRETE PIPE



STANDARD 48-INCH CULVERT PIPE, CHICAGO & NORTH WESTERN RAILWAY.

REPORT OF COMMITTEE XII—ON RULES AND ORGANIZATION.

Jos, Mullen, *Chairman;*
O. F. Barnes,
W. C. Barrett,
L. L. Beall,
H. L. Browne,
J. B. Carothers,
S. E. Coombs,
E. J. Correll,
Curtis Dougherty,
H. H. Edgerton,
W. H. Finley,

F. D. Anthony, *Vice-Chairman;*
B. Herman,
A. J. Himes,
F. D. Lakin,
B. M. McDonald,
H. A. Osgood,
E. T. Reisler,
W. H. Rupp,
P. T. Simons,
R. E. Warden,

Committee.

To the American Railway Engineering Association:

The Board of Direction assigned the following subjects to your Committee:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Prepare a "Manual of Instructions for the Guidance of Engineering Field Parties."
3. Continue the study of Science of Organization.
4. Prepare a "Manual of Rules for the Guidance of Employés of the Maintenance of Way Department."

Sub-Committees were appointed to deal with the above-mentioned subjects.

COMMITTEE MEETINGS.

The Committee met at the office of the Association in Chicago, July 11, 1917, six members being present. In addition, meetings were held at various times and places by the Sub-Committees.

PROGRESS REPORTS.

A large amount of work has been done on the subjects given the Committee, but the material is not in final form for presentation. The Committee therefore asks for further time in which to present complete reports of the topics referred to it.

SCIENCE OF ORGANIZATION.

Under this topic the Committee has had compiled a bibliography, which is given in Appendix A.

Respectfully submitted,

The Committee on Rules and Organization.

Appendix A.

(3) THE SCIENCE OF ORGANIZATION.

A. J. HIMES, Chairman, Sub-Committee.

Five successive years the Directors have assigned to the Committee on Rules and Organization the study of scientific management. Throughout this time very little has been done, apparently, because of a lack of interest on the part of the Association. We are missing a great opportunity. To-day when the importance of human organization in every form transcends all other needs, we come empty-handed, not having foreseen and provided against the present extremity.

We should focus upon the subject all the powers and resources of scientific learning and experience. Scientific methods of investigation and research should be applied for the purpose and with the expectation of writing a formula with which to guide those who are called upon to direct the affairs of their fellow-men. We should clearly discern the need. A thorough and exhaustive consideration and discussion should be had of the necessity and the utility of organization. A like treatment should then be given to the resources which may be used in its development. Having shown the need and discovered the resources, attention should be given to their application and a means of solution presented for any specific problem.

It is hoped that some interest may be aroused among the members and a discussion started which will bring forth a series of monographs. Out of the abundant experience and careful thought of our members we should give freely to the world in its hour of trial.

The discussion in the beginning might well be abstract and scientific. At a later date it should pertain directly to the practical and important application of scientific principles to railroad operation. It will be conceded that a careful study of the subject in the unrivaled manner available in our Society will achieve far better results than individual study, and no better justification for our being exists at present. To facilitate the study and discussion, the Committee submits a bibliography in which one can readily find abundant information and suggestions for various methods of treatment.

Charts have been secured illustrating the maintenance organizations on many of the leading roads. These charts can be furnished by the Committee on request, and if desired they may at a later date be published in a Bulletin.

BIBLIOGRAPHY ON THE SCIENCE OF ORGANIZATION.

"Organization and Management"; by Lee Galloway. N. Y., 1910. Alexander Hamilton Institute. (The author attempts a survey of the economic structure of society in which each concern fills its own separate place; a study of the internal organization of a business and the activities and direction of a going business.)

"The Psychology of Management"; by L. M. Gilbreth. N. Y., 1914. Sturgis and Walton Company. $1.80. (On the function of the mind in determining, teaching and installing methods of least waste. The author states that it is not the purpose of the book to give a detailed account of management in general or of the Taylor plan of "Scientific Management" in particular.)

"The American Office, Its Organization, Management and Records"; by J. William Schulze. N. Y., 1913. Key Publishing Company. (Contains brief data on principles of organization; deals largely with application of methods.)

"Analysis of Employment and Departmental Organization Charts," City of Chicago, March, 1913. Chicago, Ill., 1913. Civil Service Commission, J. Lewis Jacobs, Efficiency Engineer in Charge. (Contains charts of the staff and line organization of the Chicago city departments.)

"The Modern Building Organization"; by Louis Jay Horowitz. N. Y., 1911. Alexander Hamilton Institute, Astor Place. (Pamphlet discussing principles of organization of building corporations and giving a chart of the organization of the Thompson-Starrett Company.)

"Executive Control." "The Factory Management Series," v. 2. Chicago, 1915. A. W. Shaw Company. (On building up the organization, selecting and training the men, reorganizing under scientific ties, decisions and policies.)
management, establishing written standard practice, management du-

"The Economic Side of Works Management"; by John Christie Duncan, 1911. A thesis presented to Faculty of the Graduate School of the University of Pennsylvania. (Contains a chapter discussing briefly the three types of organization, the military, the fundamental and the departmental methods.)

"The Successful Operation of a System of Scientific Management"; by Frank W. Sterling. In "Scientific Management," p. 296; by Clarence Bertrand Thompson. Cambridge, 1914. Harvard University Press. $3.60. (Organization is briefly outlined.)

"Scientific Management in Business"; by A. W. Shaw. In "Scientific Management," p. 217; by C. B. Thompson. Cambridge, 1914. (Very brief discussion.)

"The Science of Management"; by G. J. Meyers. In "Scientific Management," p. 132; by C. B. Thompson. Cambridge, 1914. (Very brief.)

"Efficiency as a Basis for Operation and Wages," p. 58; by Harrington Emerson. N. Y., 1911. The Engineering Magazine. $2. (Compares line and staff organization.)

"Factory Administration and Accounts," p. 27; by Edward T. Elbourne. London, 1914. Longmans, Green and Co., 39 Paternoster Row. $7.50. (Contains brief data on staff organization, with representative diagrams.)

"Modern Organization, an Exposition of the Unit System"; by Charles DeLano Hine. N. Y., 1912. The Engineering Magazine Company. $2. (Describes the unit system on the Harriman lines and has other chapters on operation of the unit system; broadening the ideals of line supervision; overspecialization; fallacies of accounting; supplies and purchases; line and staff; genesis and revelation of organization.)

"Industrial Organization." The Library of Business Practice, vol. 2. Chicago, 1914. A. W. Shaw Company. (Contains monographs on working out a plan of control; building and equipping the plant; selecting a wage payment method; and getting out the product.)

"Getting the Most out of Business," p. 311; by E. St. Elmo Lewis. N. Y.,

1915. The Ronald Press Company. $1.80. (Contains chapters on the executive organization; and the line and staff system.)

"Cost Keeping and Scientific Management," p. 136; by Holden A. Evans. N. Y., 1911. The McGraw-Hill Book Company. $2.70. (Contains a chapter on the principles of scientific management, which can be followed by a manager.)

"The Cost of Manufactures and the Administration of Workshops, Public and Private," p. 27; by Henry Metcalfe. N. Y., 1885. John Wiley & Sons, 432 Fourth Avenue. (Contains seven pages on organization of an arsenal, showing the relations of the principal officers and employees.)

"Industrielle Verwaltungstechnik," p. 27; by S. Herzog. Stuttgart, 1912. Ferdinand Enke. $3.23. (Contains data on industrial organization.)

"Works Management," p. 100; by William Duane Ennis. McGraw-Hill Book Company, 239 West 39th Street. $2. (Discusses pure line administration, as in the army, in which each division is complete in itself and all divisions responsible to one head, and also discusses revised form of line organization; states that this method is generally used in the administration of a railroad.)

"The Science and Practice of Management"; by A. Hamilton Church. N. Y., 1914. The Engineering Magazine Company, 140 Nassau Street. $2. (The author attempts to exhibit and delimit the five organic functions of manufacturing management, i. e., design, equipment, control, comparison and operation; and to demonstrate how the three laws of effort influences their working, i. e., experience must be standardized, economically regulated and personal effectiveness must be promoted.)

"Factory Organization and Administration," p. 31; by Hugo Diemer. N. Y., 1910. McGraw-Hill Book Company, 239 West 39th Street. $3 net. (Advocates centralized control, so organized that each department head is responsible to the works manager without any intervening bosses, gives a typical manufacturing organization, an automobile shop and a strictly engineering shop.)

"Principles of Industrial Organization"; by Dexter S. Kimball. N. Y., 1913. McGraw-Hill Book Company. $2.50. (The author attempts to give general principles only; chapter seven discusses, briefly, military or line organization, staff organization, line and staff organization, co-ordination and executive control, etc.)

"The Commercial Management of Engineering Work"; by Francis G. Burton. Edition 2. Manchester, England. The Scientific Publishing Company. 12 shillings, 6 pence net. (Contains data on the duties of director, secretary and general manager.)

"The Twelve Principles of Efficiency," p. 27; by Harrington Emerson. N. Y., 1912. Eng. Magazine. (Contains a chapter on type of organization through which efficiency is attained.)

"The Principles of Scientific Management;" by Frederick Winslow Taylor. N. Y., 1911. Harper & Brothers, Publishers. (On the science of the Taylor system of manageemnt. Advocates an almost equal division of the work and the responsibility between the management and the workmen; the management to take over all work for which they are better fitted than the workmen, while in the past almost all of the work and the greater part of the responsibility were thrown upon the men.)

"Organization of the Operating Department of Railroads;" by R. H. Aishton. In "Railway Organization and Working," p. 141; edited by Ernest Ritson Dewsnup. Chicago, 1906. University of Chicago Press. $2 net. (Five and a half pages on railroad organization, giving as an example that of the Chicago & North Western Railway.)

"Economics of Railway Operation;" by M. L. Byers. N. Y., 1908. Engineering News Publishing Company (now the Hill Publishing Co.), Tenth Avenue and 36th Street. $5 net. (Contains a chapter discussing effects of centralization and divisional vs. departmental organization.)

"Handbook of Machine Shop Management;" by John H. Van Deventer. N. Y., 1915. McGraw-Hill Book Company, Inc., 239 West 39th Street. $2.50. (Contains a very brief discussion of line and staff organization, with charts.)

"Railroad Administration;" by Ray Morris. N. Y., 1910. D. Appleton & Company. $1.80. (On the organization required for the management of small and large railroads; divisional versus departmental organization; the officers; comparison of British and American railroad organization and government railroad organization.)

"Maximum Production in Machine-Shop and Foundry," p. 17; by C. E. Knoeppel. N. Y., 1911. The Engineering Magazine. $2.50. (Contains a chapter discussing the importance of efficient organization.)

"Installing Efficiency Methods," p. 67; by C. E. Knoeppel. N. Y., 1915. The Engineering Magazine. $3. (Contains a chapter on organization.)

"Principles of Industrial Engineering," p. 39; by Charles Buxton Goring. N. Y., 1911. McGraw-Hill Book Company, 239 W. 39th St. $1.80. (Contains a chapter on principles of industrial organization.)

"Mechanical Department Organization." American Engineer, v. 86, p. 118, March, 1912. (Organization chart for the motive power department of the Illinois Central Railroad.)

"Improving Operating Conditions in Small Plants;" by Marshall Milton. American Gas Light Journal, v. 100, p. 289 (May 11, 1914). (Gives organization diagram.)

"The Principles of Management;" by A. Hamilton Church and L. P. Alford. American Machinist, v. 36, p. 857 (May 30, 1912). (Four and a half pages.)

"Another Side of Efficiency Engineering;" by Dexter Kimball. Am. Mach., v. 35, p. 263 (Aug. 10, 1911). (Gives principles of new industrial efficiency.)

"Has Scientific Management Science?" by A. Hamilton Church. Am. Mach., v. 35, p. 108 (July 20, 1911). (Four and a half pages.)

"Scientific Factory Management;" by Holden A. Evans. Am. Mach., v. 33, Pt. 1, p. 1108 (June 16, 1910). (Three and a half pages.)

"Reduction Cost of Navy Yard Work;" by Holden A. Evans. Am. Mach., v. 33, Pt. 1, p. 1200 (June 30, 1910). (The application of Scientific management to navy yard work; three pages.)

"The Principles of Scientific Management;" by Frederick W. Taylor. Applied Science, new series, v. 7, p. 76 (Jan. 1913). Four and a half pages.

"Mr. Fairfax Harrison's Scheme of Industrial Co-Operation Applied to Railway Operation;" by H. Marchand. Bulletin, International Railway Congress, v. 27, p. 995 (Dec., 1913). (On administrative problems from the psychological point of view; nine pages.)

"Essentials of an Engineering Office Organization;" by Wilfred G. Astle. Canadian Engineer, v. 28, p. 602 (May 27, 1915). (A very brief article.)

"Scientific Management and Science;" by P. Ballard. Cassier's Magazine, v. 41, p. 425 (May, 1912). (Six pages.)

"Manager and Scientist;" by H. F. Stimpson. Cassier's Magazine, v. 41, p. 319 (April, 1912). (Six and a half pages.)

"The Boston Elevated Organization (Editorial), Electric Railway Journal, v. 41, p. 240 (Feb. 8, 1913). (Three quarters of a page.)

"Maintenance Shop Organization for City Lines;" by J. C. Thirlwall. Electric Railway Journal, v. 40, p. 406 (Sept. 14, 1912).

"The Organization of the Electrical Industry;" by C. Ashmore Baker. The Electrical Review (London), v. 75, p. 46 (July 10, 1914). (One and a half pages.)

"Central-Station Sales Department, Organization and Work;" by F. D. Beardslee. Electrical Review and Western Electrician, v. 65, p. 1073 (Dec. 5, 1914). (Gives organization chart.)

"Staff Organization in an Ice-Electric Plant." Electrical World, p. 1395, v. 63 (June 13, 1914). (Gives an organization chart of the ice-electric company; three quarters of a page.)

"Reorganization of the Department of Electricity, Chicago." Electric World, v. 62, p. 222 (Aug. 2, 1913). (Gives organization chart.)

"Centralized Management of Electrical Properties;" by H. S. Knowlton. Elec. World, v. 41, p. 880 (May 23, 1903). (One and a quarter pages.)

"Organization in Electrical Undertakings;" by C. M. Shaw. The Elecn., v. 69, p. 459 (June 21, 1912). (Three and a half pages.)

"Industrial Management" (Editorial). Engineering, v. 95, p. 877 (June 27, 1913). (One page.)

"Notes on Engineering Workshop Organization"; by R. Douglas Heap. Engineering, v. 79, p. 230 (Feb. 17, 1905). (Two and a half pages.)

"Essentials of Organization and Management"; by J. R. Finlay. Engineering and Mining Journal, v. 100, p. 171 (July 31, 1915). Five and a half pages.

"Experience at Inglewood, Cal., with the City Manager Form of Government." Engineering Contracting, v. 42, p. 465 (Nov. 11, 1914). (Discusses briefly the principles of this form of government.)

"Scientific Management for the Factory of Moderate Size"; by Dwight T. Farnham, Engineering Magazine, v. 50, p. 46 (Oct., 1915). (In a small plant, Mr. Farnham developed a Superintendent-Staff, Asst. Superintendent-Line organization.)

"The Ultimate Type of Management"; by John H. Van Deventer. Engr. Mag., v. 49, p. 394 (June, 1915). (Mr. Van Deventer takes as an example the human nervous system to prove that the line and staff type of organization is the ideal scheme of management.)

"The Practical Introduction of Efficiency Principles," Pts. 3, 4, 5, 7; by C. E. Knoeppel. Eng. Mag., v. 46, p. 943; v. 47, pp. 65, 241, 570 (March, April, May, July, 1914). (A study of the duties of the executive department of an organization in relation to a campaign for betterment.)

"The Administrator as Scientist"; by Edward D. Jones. Eng. Mag., v. 47, pp. 163, 370, 491 (May, June, July, 1914). (Study of the world's great scientists, to find therein methods applicable to business.)

"The Administrator as Diplomat"; by Edward D. Jones. Eng. Mag., v. 47, pp. 715, 841; v. 48, p. 23 (Aug., Sept., Oct., 1914). (History, methods and ideals of the gentleman-administrator.)

"Francis Bacon, Efficiency Engineer"; by H. D. Minich. Eng. Mag., v. 47, p. 735 (Aug., 1914). (Three pages.)

"Force Organization in the Railroad Repair Shop"; by Ernest Cordeal. Eng. Mag., v. 45, p. 548 (July, 1913). (Proposals for the betterment of railway management by effort originating and applied within the organization; eight pages.)

"The Organization of Large Commercial and Industrial Establishments"; by Benno Orenstein. Eng. Mag., v. 44, p. 588 (Jan., 1913). (Outline of a working industrial administration.)

"Military History and the Science of Business Administration"; by Edward D. Jones. Eng. Mag., v. 44, pp. 1, 185, 321 (Oct., Nov., Dec., 1912). (A study of administrative principles, reviewing military policies as suggestive of analogies interesting from a business viewpoint.)

"Practical Principles of Rational Management"; by A. Hamilton Church. Eng. Mag., v. 44, pp. 487, 673, 894; v. 45, pp. 24, 166, 405 (Jan., Feb., March, April, May, June, 1913). (The author attempts to reduce to concise expression the certainty established principles of successful business administration as determined not only by scientific experiment, but by practical experience and common sense. He presents the subject under six headings: The Product, the Machine, the Work, the Man, What to Plan and When, What to Record and How.)

"The Efficient Manufacture of Railway Transportation"; by Harrington Emerson. Eng. Mag., v. 43, p. 341; v. 44, p. 481 (June, 1912; Jan., 1913). (Uses the Pittsburgh & Lake Erie Railroad as an example of the realization of the principles and precepts of efficiency.)

"Modern Organization"; by Charles DeLano Hine. Eng. Mag., v. 42, pp. 481, 720, 869; v. 43, pp. 44, 217, 348, 588 (Jan., Feb., March, April, May, June, July, 1912). (Treats of the unit system on the Harriman lines; broadening the idea of supervision; over-specialization; fallacies of accounting; supplies and purchases; line and staff and the genesis and revelation of organization.)

"The Problem of the Minor Executive"; by H. Kieth Trask. Eng. Mag., v. 38, p. 497 (Jan., 1910). (Six pages.)

"Organization by Production Factors"; by A. Hamilton Church. Eng. Mag., v. 38, pp. 15, 184, 361, 557, 703, 863 (Oct., Nov., Dec., 1909; Jan., Feb., March, 1910). (Treats of the definition of factors other than labor; production factor as related to cost accounts and staff; elements of the land factor, etc.)

"Management Principles and the Consulting Engineer"; by Charles Day. Eng. Mag., v. 41, p. 133 (April, 1911). (Eight pages.)

"The Meaning of Scientific Management"; by A. Hamilton Church. Eng. Mag., v. 41, p. 97 (April, 1911). (Four and a half pages.)

"Prerequisites to the Introduction of Scientific Management"; by H. K. Hathaway. Eng. Mag., v. 41, p. 141 (April, 1911). (Six pages.)

"The Organization of Great Corporations"; by Wm. W. Mulford. Eng. Mag., v. 40, p. 240 (Nov., 1910).

"Sanity in Naval Organization." Eng. Mag., v. 38, p. 489 (Jan., 1910). (Eight pages.)

"The Basic Cause of Increased Efficiency"; by Walter M. McFarland. Eng. Mag., v. 36, p. 329 (Dec., 1908). (Seven pages.)

"Efficiency as a Basis for Operation and Wages," Pt. 4; by Harrington Emerson. Eng. Mag., v. 36, p. 33 (Oct., 1908). (On standards, their relation to organization and results.)

"Maximum Production through Organization and Supervision"; by C. E. Knoeppel. Eng. Mag., v. 35, p. 82 (April, 1908). (Ten pages.)

"Engineering Organization in the Building of Industrial Plants"; by Frederic W. Bailey. Eng. Mag., v. 35, p. 239 (May, 1908). (Twelve pages.)

"The Fundamental Principles of Works Organization and Management"; by P. J. Darlington. Eng. Mag., v. 34, p. 1029 (March, 1908). (Ten pages.)

"The Production System of the Westinghouse Electric & Mfg. Co."; by H. M. Wharton. Eng. Mag., v. 34, p. 891 (March, 1908). (Contains a general outline of the organization.)

"The Management of Production in a Great Factory"; by George F. Stratton. Eng. Mag., v. 34, p. 569 (Jan., 1908). (Division of responsibility and authority in the General Electric Co.'s shops.)

"The Meaning of Commercial Organization"; by A. Hamilton Church. Eng. Mag., v. 20, p. 391 (Dec., 1900). (Advocates more co-ordination in different departments of a commercial organization.)

"The Manager Plan of Municipal Government"; by Kenyon Riddle. Engineering News, v. 71, p. 831 (April 16, 1914). (Gives the working principles of this form of municipal government.)

"New York State Road Organization." Eng. News, v. 70, p. 982 (Nov. 13, 1913). (Makes a brief statement of the fundamental principles upon which the basis of an efficient organization must rest.)

"The Economic Administration of Industrial Establishments"; by John Calder. Eng. News, v. 66, p. 570 (Nov. 9, 1911). (Uses the organization and system in the Remington Typewriter Works, Ilion, N. Y., as an illustration; four and a half pages.)

"Social Philosophy and the Taylor System" (Letter); by Winslow H. Herschel. Eng. News, v. 65, p. 577 (May 11, 1911). (One page.)

"Organization Methods for $10,000,000 Track Elevation Program." Engineering Record, v. 70, p. 122 (Aug. 1, 1914). (Contains diagram of organization for Rock Island track-elevation work.)

"Organization of an Engineering Construction Company." Eng. Rec., v. 68, p. 187 (Aug. 16, 1913). (One and a quarter pages.)

"Organization of the Bureau of Water Supply, City of New York"; by I. M. DeVarona. Eng. Rec., v. 65, p. 664 (June 15, 1912). (Includes an organization chart; one and a half pages.)

"The Application of Scientific Management to the Activities of State and Municipal Governments"; by Frederick A. Cleveland, Eng. Rec., v. 64, p. 653 (Dec. 2, 1911). (Two and a half pages.)

"The Engineering Organization of the Western Pacific Railway Co."; by George F. Low. Eng. Rec., v. 56, p. 117 (Aug. 3, 1907). (Two and a half pages.)

"The New Engineering Organization on the Rock Island System." Eng. Rec., v. 50, p. 286 (Sept. 3, 1904). (One page.)

"Le Systeme Taylor, Communication Faite, le 13 janvier, a la Societe d'Encouragement pour l'Industria nationale par M. Ch. de Freminville." Le Genie Civil, v. 64, p. 250 (Jan. 24, 1914). (Gives a diagram of the Gilbreth scientific organization chart.)

"Scientific Management and the Labor Problem"; by Robert Thurston Kent. Industrial Engineering, v. 14, p. 418 (Nov., 1914). (Four pages.)

"The Practical Working of Scientific Management." Ind. Eng., v. 14, p. 224 (June, 1914). (Four pages.)

"The General Manager, a Study of the Qualities which go to make a Good Executive"; by William Kent. Ind. Eng., v. 14, p. 197 (May, 1914). (One and a half pages.)

"The Basis of Construction Management"; by Frederick A. Waldron. Ind. Eng., v. 14, p. 155 (April, 1914). (Two pages.)

"The Preliminary Steps for Efficient Management"; by Frederic A. Parkhurst. Ind. Eng., v. 14, p. 25 (Jan., 1914). (Three and a quarter pages.)

"Organized Labor and Scientific Management"; by Horace B. Drury. Ind. Eng., v. 14, pp. 99, 145, 191 (March, April, May, 1914). (States that this is a careful analysis of what management does for labor and the opinion of labor leaders.)

"Practical and Scientific Management, the Taylor System from the Viewpoint of a German Engineer"; by G. Schlesinger. Ind. Eng., v. 14, p. 376 (Sept., 1913). (Five pages.)

"Industrial Management, Scientific Management as Related to the Plant or Industry in its Entirety"; by James Mapes Dodge. Ind. Eng., v. 13, p. 330 (Aug., 1913). (Three pages.)

"The Psychology of Management"; by L. M. Gilbreth. Industrial Eng., v. 11, p. 343, 429; v. 12, pp. 13, 65, 116, 155, 199, 248 (May, June, July, Aug., Sept., Oct., Nov., Dec. 1912). (Published also in book form.)

"Scientific Management under the X-Ray." Iron Age v. 96, p. 1236 (Nov. 25, 1915). (Abstract of report of the special investigator of the Federal Industrial Relations Commission.)

"The Three-Position Plan of Promotion"; by F. B. and L. M. Gilbreth. Iron Age, v. 96, p. 1056 (Nov. 4, 1915). (Two and a half pages.)

"System and Its Abuse"; by John Calder. Iron Age, v. 96, p. 1043 (Nov. 4, 1915). (One page.)

"The Individual in Modern Management"; by F. B. and L. M. Gilbreth. Iron Age, v. 96, p. 802 (Oct. 7, 1915). (Two and a half pages.)

"The Co-Operative Spirit and Industrial Peace"; by F. B. and L. M. Gilbreth. Iron Age, v. 96, p. 528 (Sept. 2, 1915). (A contribution to the sociology of management; two and a half pages.)

"The Executive's Problem"; by George D. Babcock. Iron Age, v. 96, p. 419 (Aug. 19, 1915). (An analysis of what is involved in different forms of management; one page.)

"No Victory over Scientific Management"; by George De A. Babcock. Iron Age, v. 93, p. 1402 (June 4, 1914). (What four years of the Taylor system have proved at the plant of the H. H. Franklin Mfg. Company, Syracuse; three pages.)

"The Taylor System from a German Viewpoint"; by G. Schlesinger. Iron Age, v. 92, p. 82 (July 10, 1913). (Two pages.)

"Science Applied to Industrial Management"; by James Mapes Dodge. Iron Age, v. 91, p. 1544 (June 26, 1913). (Two pages.)

"Management of Small Versus Large Plants"; by Stuart Dean. Iron Age, v. 91, p. 1377 (June 5, 1913). (A brief for the foreman of large authority over a few men; splitting a factory into independent units; half a page.)

"Questions on Scientific Management. A Chicago Conference at which the Taylor System is Opposed and Defended." Iron Age, v. 91, p. 743 (March 20, 1913). (Three quarters of a page.)

"The Science and the Art of Management"; by F. G. Coburn. Iron Age, v. 91, p. 248 (Jan. 23, 1916). (A plea for training in the psychological principles of handling men, confusion over management as a science; one and a quarter pages.)

"The Taylor System in Government Shops." Iron Age, v. 89, p. 726 (March 21, 1912). (The report of the House Committee to investigate various systems of shop management is in general adverse; two and a half pages.)

"The Human Side of Business Organization"; by Sterling H. Bunnell. Iron Age, v. 89, p. 29 (Jan. 4, 1912). (Three quarters of a page.)

"Modern Business Methods"; by Wallace M. Pattison. Iron Age, v. 87, p. 905 (April 13, 1911). (Gives a definition of organization.)

"Works Administration as a Constructive Science"; by H. F. Stimpson. Iron Age, v. 87, p. 248 (Jan. 26, 1911). (On the development of directive methods, the use of standards and records.)

"Business Administration as a Constructive Science"; by H. F. Stimpson. Iron Age, v. 87, p. 662 (March 16, 1911). (On the apportionment of physical force, the apportionment of mental force and the coordinate divisions of business.)

"Business Administration as a Constructive Science, a Discussion of Organization Standards and Records"; by H. F. Stimpson. Iron Age, v. 87, p. 722 (March 23, 1911). (Two and a quarter pages.)

"The Organization of Industrial Works; a German Engineering View of the Question." Iron and Coal Trades Review, v. 80, p. 643 (April 29, 1910). (One and a quarter pages.)

"Staff Organization in Large Manufacturing Plants"; by W. H. A. Robertson. Iron and Coal Trades Review, v. 77, p. 2000 (Nov. 6, 1908). (Half a page.)

"The Successful Operation of a System of Scientific Management"; by Frank W. Sterling. Journal, American Society of Naval Engineers, v. 24, p. 167 (Feb., 1912). (The application of the Taylor system with organization chart.)

"The Fetishism of Scientific Management"; by John R. Edwards. Jour. Am. Soc. Naval Engrs., v. 24, p. 355 (May, 1912). (Sixty-one pages.)

"The Science of Management"; by G. J. Meyers. Jour. Am. Soc. Naval Engrs., v. 23, p. 994 (Nov., 1911). (Twelve pages.)

"The Commission-Manager Form of Government"; by Henry M. Waite. Jour. Association of Engineering Societies, v. 52, p. 249 (May, 1914). (A brief description of the application to a municipality of the newest development in organization.)

"Railroad Organization"; by George T. Sampson. Jour. Assoc Eng. Soc., v. 28, p. 1 (Jan., 1902). (Thirty-one pages.)

"The Commission-Manager Form of Government and its Relation to the Engineering Profession"; by Henry M. Waite. Journal, Boston Society of Civil Engineers, v. 2, p. 1 (Jan., 1915). (Discussion of this form of organization.)

"Scientific Management and the Interests of the Employee"; by H. K. Hathaway. Journal, Engineers' Society of Pennsylvania, v. 7, p. 66 (Jan., 1915). (Six and a half pages.)

"Industrial Organization"; by Hugo Diemer. Journal of the Engineers' Society of Pennsylvania, v. 4, p. 317 (Oct., 1913). (28 pages.)

"The Practical Application of Scientific Management to Railway Operation"; by Wilson E. Symons. Journal of the Franklin Institute, v. 173, pp. 1, 141, 271, 365 (Jan., Feb., March, April, 1912). (On the physical management of a railroad by scientific methods.)

"Presidential Address, Iron and Steel Institute"; by Andrew Carnegie. Journal, Iron and Steel Institute, v. 63, p. 32 (1903, No. 1). George C. Lloyd, Secretary, 28 Victoria Street, London, S. W., England. (Twenty-two pages.)

"Abstract. The Organization of Manufacturing Industries." Eng. News, v. 49, p. 436 (May 14, 1903). (One and a quarter pages.)

"Construction Management"; by Sanford E. Thompson and William O. Lichtner. Journal, Western Society of Engineers, v. 20, p. 109 (Feb., 1915). (States, as one of the principles of scientific management, that there is an almost equal division of the work and responsibility between the management and the workmen.)

"Organization, an Outline of Essentials from Engineering Practice"; by T. C. Roberts. Metallurgical and Chemical Engineering, v. 11, p. 95 (Feb., 1913). (Organization charts showing business passing to department heads through assistants and showing assistant department heads acting only on consultation with department heads.)

"The City Manager, the Latest Plan for Municipal Management"; by Paul E. Dressly. Municipal Engineering, v. 47, p. 15 (July, 1914). (Four pages.)

"Government of Cities, Commissions and Departments Compared and Contrasted"; by Nelson P. Lewis. Mun. Eng., v. 46, p. 449 (May, 1914). (Three and a half pages.)

"The Principles of Scientific Management as Applied to Highway Engineering"; by Frank B. Gilbreth. Municipal Engineering, v. 46, p. 474 (May, 1914). (Two pages.)

"Organization at Delray"; by Norman G. Reinicker. Power, v. 42, p. 343 (Sept. 7, 1915). (Gives organization chart of the Delray power plants.)

"Efficiency in Railway Management"; by L. W. Wallace. Proceedings, Indiana Engineering Society, v. 32, p. 111 (1912). (Charles Brossman, Secy., Union Trust Building, Indianapolis, Indiana. 50 cents. (States that an important step in railway efficiency is the unit system of organization on the Harriman lines.)

"Naval Personal Legislation"; by D. W. Knox. Proceedings, United States Naval Institute, v. 39, p. 1607 (Dec., 1913). (Ten pages.)

"Organization. An Essay on Fundamental Principles with Special Reference to the Navy"; by C. S. Radford. Proc., U. S. Naval Inst., v. 39, p. 1683 (Dec., 1913). (Thirty-five pages.)

"Maintenance of Way Organization"; by H. R. Safford. Purdue Engineering Review, v. 4, p. 59 (1908). (The author is the Chief Engineer of the Maintenance of Way, Illinois Central Railway; discusses departmental organization.)

"Organizing the Supply on the Seaboard Air Line"; by H. C. Pearce. Railway Age Gazette, v. 58, p. 45 (Jan. 8, 1915). (States that sufficient facilities and no division of authority proved to be the essentials of success of this organization.)

"The Superintendent—Past, Present and Future"; by E. H. DeGroot, Jr. Ry. Age Gaz., v. 58, p. 181 (Jan. 29, 1915). (One page.)

"The General Manager's Supervision over Division Performance." Ry. Age Gaz., v. 58, p. 360. (On conditions on the Western Maryland Railroad; one and a half pages.)

"Wanted—Directors Who Will Direct (Editorial)." Ry. Age Gaz., v. 50, p. 814 (April 16, 1915). (Action of directors of the Rock Island Railroad.)

"Organization in the Maintenance of Way Department (Editorial)." Ry. Age Gaz., v. 58, p. 834 (April 16, 1915). (Half a page.)

"Vice-President in Charge of Labor" (Letter); by J. Lowell White. Ry. Age Gaz., v. 58, p. 997 (May 14, 1915). (On proposed duties for a vice-president.)

"How the Operation of One Terminal was Improved"; by G. D. Brooke. Ry. Age Gaz., v. 58, p. 1121 (May 28, 1915). (States that continued serious congestion was overcome by change in organization, better methods and improved discipline; shows yard organization chart.)

"The Mechanical, Purchasing and Stores Departments"; by H. C. Pearce. Ry. Age Gaz., v. 58, p. 1249 (June 11, 1915). (On the relations between these three departments, organization necessary to get both economy and co-operation.)

"The General Office Clerk, a Neglected Factor"; by George A. Clark. Ry. Age Gaz., v. 57, p. 64 (July 10, 1914). (Bureaus suggested to specialize in appliances and methods and in selection of men for this department.)

"Organization of the Maintenance of Way Department of the Pennsylvania Railroad." Ry. Age Gaz., v. 57, p. 119 (July 17, 1914). (One page.)

"Organization"; by R. V. Taylor. Ry. Age Gaz., v. 57, p. 389 (Aug. 28, 1914). (States that the official most important in any railroad organization is the superintendent; half a page.)

"Proper Organization and Economical Use of Labor and Material"; by P. J. McAndrews. Ry. Age Gaz., v. 57, p. 503 (Sept. 18, 1914). (On track organization; one page.)

"Conditions that Hamper the English Railway Manager" (Letter); by Charles Hansel. Ry. Age Gaz., v. 56, p. 413 (Feb. 27, 1914). (One page.)

"Organizing for Important Track Elevation Work." Ry. Age Gaz., v. 56, p. 535 (March 13, 1914). (Rock Island Railroad method of handling heavy construction work with company forces.)

"The Agency Plan on the St. Louis & San Francisco." Ry. Age Gaz., v. 56, p. 671 (March 20, 1914). (Results obtained by making agents responsible for traffic.)

"Railway Organization"; by Charles Hine. Ry. Age Gaz., v. 56, p. 794 (April 3, 1914). (Three-quarters of a page.)

"Who are the Bosses of our Railways?" by George A. Post. Ry. Age Gaz., v. 56, p. 951 (April 24, 1914). (One page.)

"Railway Storekeepers' Association." Ry. Age Gaz., v. 56, p. 1195 (May 29, 1914). (Abstract of paper by W. D. Stokes; half a page.)

"Some Suggestions for More Efficient Organization" (Letter); by N. E. Bailey. Ry. Age Gaz., v. 55, p. 216 (Aug. 8, 1913). (Contains a chart with suggestions for railway organization; one and a half pages.)

"The Supply Department of the Railway"; by George G. Yegmans. Ry. Age Gaz., v. 55, p. 857 (Nov. 7, 1913). (Its purposes and functions and their importance, and its proper place in the organization of the operating department.)

"Operating Organization on the Canadian Pacific." Ry. Age Gaz., v. 54, p. 19 (Jan. 3, 1913). (It is divided into four divisions with a general superintendent in charge of each.)

"A Suggested Organization for Combined Forces" (Letter); by F. W. Rizer. Ry. Age Gaz., v. 54, p. 339 (Feb. 21, 1913). (Gives chart for a proposed organization for maintenance of way dept.)

"A Reverie on the Unit System" (Letter). Ry. Age Gaz., v. 54, p. 1021 (May 9, 1913). (Half a page.)

"Studies in Operation, the M. K. & T." Ry. Age Gaz., v. 54, p. 1167 (May 30, 1913). (Contains a chart showing the divisional form of organization on the Misouri, Kansas & Texas.)

"The Working of the Hine Unit System" (Letter). Ry. Age Gaz., v. 54, p. 1307 (June 13, 1913). (One page.)

"Recent Developments in the Unit System of Organization." Ry. Age Gaz., v. 52, p. 480 (March 15, 1912). (A study of the Hine system of organization as adopted on the Harriman lines.)

"Organization of the Philadelphia & Reading." Railroad Gazette, v. 36, p. 172 (March 11, 1904). (Gives chart and brief explanation of a "strong divisional organization.")

"Organization of the Chicago Great Western." R. R. Gaz., v. 36, p. 173 (March 11, 1904). (A diagram of the operating organization, divisional in character.)

"Some Thoughts and Suggestions on Railroad Organization and Management"; by A. M. Waite. R. R. Gaz., v. 36, p. 173 (March 11, 1904). (One and a half pages.)

"Railroad Organization"; by Arthur Hale. R. R. Gaz.; v. 34, p. 264 (April 11, 1902). (Two pages, including diagrams.)

"Organization of the Pennsylvania Railroad." R. R. Gaz., v. 32, p. 268 and inset (April 27, 1900). (A double-page plate, giving organization chart and a very brief explanation.)

"The Organization of a Great Railroad" (Editorial). R. R. Gaz., v. 32, p. 733 (Nov. 9, 1900). (Gives organization of the operating department of the Southern Railway Company.)

"Engine House Organization"; by W. P. Huntley. Railway Age Gazette. Mechanical Edition, v. 89, p. 135 (March, 1915). (Gives chart for engine house operation.)

"'Big Bill' Agnew and 'Blue Monday'"; by Harvey De Witt Wolcomb. Ry. Age Gazette, Mech. Edition, v. 89, p. 533 (Oct., 1915). (States

that this is a true story, showing clearly the relation of engine house organization to engine house failures.)

"Railway Repair Shop Organization"; by Henry Gardner. Ry. Age Gaz., Mech. Edition, v. 89, p. 536 (Oct., 1915). (Gives chart showing ideal form of organization for a large locomotive repair shop.)

"An Efficient Piece-Work System." Ry. Age Gaz., Mech. Edition, v. 88, p. 249 (May, 1914). (Organization chart of the Angus shops installed at Montreal by the Canadian Pacific Railway.)

"Organization of Engine House Forces"; by R. G. Gilbride. Ry. Age Gaz., Mech. Edition, v. 88, p. 477 (Sept., 1914). (Gives organization chart.)

"Taylor System"; by W. W. Scott. Ry. Age Gaz., Mech. Edition, v. 88, p. 413 (August, 1914). (One page.)

"Mechanical Department Organization of the Erie"; by R. S. Mounce. Ry. Age Gaz., Mech. Edition, v. 87, p. 645 (Dec., 1913). (Gives organization charts; two pages.)

"Engine House Organization and Operation"; by W. Smith. Ry. Age Gaz., Mech. Edition, v. 87, p. 597 (Nov., 1913). (Gives organization chart.)

"Organization for Track Maintenance." Railway Review, v. 56, p. 221 (Feb. 13, 1915).

"Increased Efficiency of Division Organization." Ry. Rev., v. 55, p. 266 (Aug. 29, 1914). (Two pages.)

"Railroad Organization"; by R. V. Taylor. Ry. Rev., v. 55, p. 250 (Aug. 29, 1914). (The author is Vice-President and General Manager of the Mobile & Ohio R. R.)

"Railway Organization and Operation in India"; by G. C. Godfrey. Ry. Rev., v. 54, p. 120 (Jan. 17, 1914). (A quarter of a page.)

"The Philosophy of Railway Management." Ry. Rev., v. 53, p. 51 (Jan. 18, 1913). (One and a quarter pages.)

"Railway Equipment Organization." Ry. Rev., v. 53, p. 94 (Feb. 1, 1913). (A quarter of a page.)

"Railroad Operating Administration"; by Edward L. Suffern. Ry. Rev., v. 53, p. 125 (Feb. 8, 1913). (Half a page.)

"Organization and Men"; by F. L. Jaudron. Ry. Rev., v. 53, p. 508 (May 31, 1913). (One and a half pages.)

"Railway Management vs. Corporate Management" (Editorial). Ry. Rev., v. 53, p. 534 (June 7, 1913).

"Engine House Efficiency." Ry. Rev., v. 53, p. 736 (Aug. 2, 1913). (Plans of Roundhouse organization for specialized engine service and for mixed engine service.)

"Le Systeme Taylor, Science Experimentale et Psychologie Ouvriere"; by Henry Le Chatelier. Revue de Metallurgie, v. 12, p. 197 (April, 1915). (Thirty-six pages.)

"Influence des Causes Psychologiques dans Direction du Usines"; by C. Revol. Revue de Metallurgie, v. 8, p. 791 (Oct., 1911). (11 pages.)

"Organization"; by H. S. Dele-Shaw. Journal of the Royal Society of Arts, v. 63, p. 947 (Oct. 8, 1915). (Two and a half pages.)

Same. Engineer, v. 120, p. 256 (Sept. 10, 1915). (Half a page.)

"The Principles of Business Management of an Architect's Office Practice"; by H. S. Kissam. School of Mines Quarterly, v. 31, p. 45 (Nov., 1909). (Eighteen pages.)

"The Business Management of the Navy"; by G. v. L. Meyer. Scientific American, v. 105, p. 513 (Dec. 9, 1911). (One page.)

"Scientific Management, the Present State of the Art." Scientific American Supplement, v. 76, p. 286 (Nov. 1, 1913). (Two pages.)

"Basic Principles of Industrial Organization"; by Dexter S. Kimball. Sibley Journal of Engineering, v. 28, p. 354 (June, 1914). (10 pages.)

"The Human Factors in Engineering Practice"; by John Calder. Stevens Institute Indicator, v. 32, p. 193 (July, 1915). (Treats of Principles of Organization.)

"The Engineering of Men"; by Willard Beahan. Stevens Institute Indicator, v. 31, p. 343 (Oct., 1914). (Includes a few informal remarks on principles in organization and on engineering organization.)

"The New Element in the Art of Management"; by John Calder. Stevens Institute Indicator, v. 30, p. 203 (July, 1913). (Discusses scientific management.)

"The Administration of Municipal Public Works. Especially Relating to Highways"; by Nelson P. Lewis. Surveyor, v. 45, p. 646 (April 17, 1914). (States the requisites necessary in order to secure satisfactory results in highway administration; centralization of authority; flexibility of organization; administrative units, etc.)

"Waterworks Management"; by Easton Devonshire. Surveyor, v. 40, p. 770 (Dec. 29, 1911).

Editorial. Surveyor, v. 40, p. 762 (Dec. 29, 1911).

"Training Engineers in the Science of Management"; by Bruce W. Benedict. The Technograph, v. 27, p. 57 (Feb., 1913). (Gives organization charts; eleven pages.)

"The Human Element the Key to the Economic Problem" (Abstract); by James Hartness. Journal, American Society of Mechanical Engr., v. 37, p. 2 (Jan., 1915). (One and a quarter pages.)

Abstracts. The Iron Age, v. 94, p. 1297 (Dec. 3, 1914); "The Human Element"; by James Hartness. American Gas Light Journal, v. 102, p. 17 (Jan. 11, 1915). (One page.)

"The Present State of the Art of Industrial Management." Report of a Committee of the American Society of Mechanical Engineers. Transactions, American Society of Mechanical Engineers, v. 34, p. 1131 (1912). (Ninety-nine and a half pages.)

Abstracts. "Management Factors other than Labor." Iron Age, v. 91, p. 256 (Jan. 23, 1913). (One and a half pages.)

"History of the Introduction of a System of Shop Management"; by James M. Dodge. Trans. Am. Soc. Mech. Engrs., v. 27, p. 720 (1906). (Three years' experience with the Taylor system of management; ten pages.)

"The Machine Shop Problem"; by Charles Day. Trans. Am. Soc. Mech. Engrs., v. 24, p. 1302 (1903). (Twenty pages.)

"Shop Management"; by Fred W. Taylor. Trans. Am. Soc. Mech. Engrs., v. 24, p. 1337 (1903). (143½ pages.)

"Railway Management and the Civil Engineer"; by Theodore Voorhees. Transactions, Association of Civil Engineers of Cornell University, v. 10, p. 33 (1902). (Twelve and a half pages.)

"Scientific Management"; by A. G. Christie.' Wisconsin Engineer, v. 17, p. 283 (April, 1913). (Outlines organization based on the Taylor system.)

"Organization and Discipline"; by M. C. Rorty. Wisconsin Engineer, v. 15, p. 197 (Feb., 1911). (An outline of the general principles of organization and discipline.)

"The Efficiency of Scientific Management"; by Addison J. Parry. Yale Scientific Monthly, v. 18, p. 142 (Dec., 1911). (Five pages.)

"The Theory and Practice of Scientific Management"; by C. Bertrand Thompson.

"Scientific Office Management"; by W. H. Leffingwell.

REPORT OF COMMITTEE XV—ON IRON AND STEEL STRUCTURES.

O. E. Selby, *Chairman;*
J. A. Bohland,
W. S. Bouton,
A. W. Carpenter,
Charles Chandler,
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H. B. Seaman,
C. E. Smith,
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H. B. Stuart,
G. E. Tebbetts,
L. F. Van Hagan,
Dr. J. A. L. Waddell,
H. T. Welty,
Committee.

To the American Railway Engineering Association:

Your Committee on Iron and Steel Structures respectfully submits herewith its annual report to the Association.

The subjects assigned the Committee by the Board of Direction are as follows:

1. Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes.
2. Report on methods of protection of iron and steel structures against corrosion.
3. Report on the relative economy of various types of movable bridges.
4. Report on secondary stresses and impact.
5. Report on column tests.
6. Report on design, length and operation of turntables.
7. Report the present practice in construction of ballast-floor bridges and methods in use for waterproofing.

COMMITTEE MEETINGS.

Since the 1917 convention the Committee has held two meetings, one at Chicago, October 18, 1917, attended by eight members, and one at New York, January 18, 1918, attended by eleven members. The usual early summer meeting was omitted, but the year's work was outlined and the Sub-Committees assigned on June 16, 1917. The Sub-Committee on Relative Economy of Various Types of Movable Bridges has held three meetings for detailed consideration of Movable Bridge Specifications. The Sub-Committee on Impact Tests during the summer conducted impact tests on the electrified section of the Chicago, Milwaukee

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*Died August 25, 1917.

& St. Paul Railway. The other Sub-Committees have done their work by correspondence.

(1) REVISION OF MANUAL.

The Committee has undertaken a revision of the subject-matter of the Association's General Specifications for Steel Railway Bridges. These specifications were adopted as part of the Committee's report to the 1906 convention, Proceedings, Vol. 7, pp. 185-207, and 236-263. There has been no substantial revision of them since.

The Committee invites constructive suggestions from members of the Association and others. It should be borne in mind that in making up a work of this character, involving many interdependent parts, it is much easier to incorporate ideas for changes in the original draft than to make changes imposed by majority vote after the draft has been submitted.

In this work, it is expected to co-operate with a corresponding committee of the Canadian Society of Civil Engineers, which has in progress a revision of that society's specifications.

Incidental to the revision of the specifications, there will have to be a revision of the rules and unit stresses for the capacity rating of existing bridges.

(2) METHODS OF PROTECTION OF IRON AND STEEL STRUCTURES AGAINST CORROSION.

The Committee is investigating the use of plastic compounds for the protection of steel work exposed to the blast action from locomotive stacks.

The Committee's report on the Schoop metal spraying process for the protection of iron and steel against corrosion follows. It is recommended that the conclusion at the end of the report be adopted and printed in the Manual.

The Committee this year has investigated the Schoop metal spraying process for the protection of iron and steel from corrosion. The process is described in the Committee's report to the 1916 convention, Proceedings, Vol. 17, page 102. It was found that laboratory tests made by certain railroads showed unsatisfactory results. In all cases it was reported that the coatings were pervious to water.

Where bronze, lead and aluminum coatings were exposed to brine, the bronze and lead coatings were practically destroyed after a few weeks' exposure; the aluminum coating was in good condition, but was raised off the plate, showing the action of rust beneath the coating.

CONCLUSION.

It is concluded from information obtainable to date that the Schoop metal spraying process does not afford satisfactory protection from corrosion.

(3) RELATIVE ECONOMY OF VARIOUS TYPES OF MOVABLE BRIDGES.

The Committee submits the Specifications for Movable Bridges, Appendix D, and recommends that they be printed in the Proceedings as information.

The purpose of these recommendations is to make the specifications available for use, and to incite constructive criticism, with the expectation that the specifications may be adopted in revised and satisfactory form for inclusion in the Manual a year or two later.

(4) SECONDARY STRESSES AND IMPACT.

The Committee's report on the impact tests made during the summer, on the electrified section of the Chicago, Milwaukee & St. Paul Railway is given in Appendix A, and the Committee recommends that it be accepted as information and printed in the Proceedings.

(5) COLUMN TESTS.

The Committee's progress report on column tests is given in Appendix B, and it is recommended that this report be printed in the Proceedings as information. It is recommended that the conclusions at the end of the report be adopted and printed in the Manual.

(6) DESIGN, LENGTH AND OPERATION OF TURNTABLES.

The Committee's report in the form of specifications for bronze bearing metals for turntables and movable bridges is submitted in Appendix C, with the recommendation that the specifications be adopted and printed in the Manual. These specifications are the result of several years' study of this subject by the Committee. Tentative specifications were submitted to the 1916 convention and were printed in the Proceedings, Vol. 17, beginning on page 107. As a result of the use made of the tentative specifications, and further study of the subject, some slight revisions have been made, and the specifications as now submitted are believed adequately to cover the present state of the art for the purposes set forth.

(7) PRESENT PRACTICE IN CONSTRUCTION OF BALLAST-FLOOR BRIDGES, AND METHODS IN USE FOR WATERPROOFING.

The Committee reports only progress on this subject, and expects to continue it during the coming year.

RECOMMENDATIONS.

The Committee recommends that the following action be taken on its report:

(1) That the conclusion under subject (2), methods of protection of iron and steel structures against corrosion, be approved.

(2) That the Specifications for Movable Bridges (Appendix D), be received as information and published in the Proceedings, with a view of revising and adopting them for inclusion in the Manual a year hence.

(3) That the report on impact tests (Appendix A), be received as information and published in the Proceedings.

(4) That the report on Column Tests (Appendix B), be received as information and that the conclusions therein be approved for publication in the Manual.

(5) That the Specifications for Bronze Bearing Metals for Turntables and Movable Railroad Bridges (Appendix C), be approved for publication in the Manual.

SUGGESTIONS FOR FUTURE WORK.

1. *Examination of the subject-matter in the Manual and definite recommendations for changes.*

(a) Revise the General Specifications for Steel Railway Bridges.

(b) Revise the rules and unit stresses for classifying and rating the capacity of existing bridges.

2. *Methods of Protection of Iron and Steel Structures against Corrosion.*

Report upon the use of plastic compounds for the protection of steel work exposed to the blast action from locomotive stacks.

3. *Relative Economy of Various Types of Movable Bridges.*

Revise the Specifications for Movable Bridges and report them for adoption.

4. *Secondary Stresses and Impact.*

(a) Report definite principles for design to reduce secondary stresses and rules for computing or allowing for them.

(b) Study and draw conclusions from records of impact tests.

(c) Continue impact tests and stress measurements as funds may be available.

5. *Column Tests.*

Continue with program of column tests as far as the work of the Bureau of Standards will permit.

6. *Design, Length, and Operation of Turntables.*

(a) Report specifications for the design of turntables and turntable pits.

(b) Report specifications for steel for turntable roller and disc bearings.

7. *Ballast Floor Bridges and Methods in Use for Waterproofing.*

Report principles for detailed design of flashing, drainage, and reinforcement for waterproofing purposes.

8. *Track Scales.*

Collaborate with the Committee on Yards and Terminals in the design of track scale superstructures.

Respectfully submitted,

THE COMMITTEE ON IRON AND STEEL STRUCTURES.

Appendix A.

IMPACT TESTS ON THE ELECTRIFIED SECTION OF THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY, 1917.

F. E. TURNEAURE, Chairman, Sub-Committee.

The question of impact under electric locomotives has been thoroughly studied by the Committee, and during the summer of 1917 some important tests were made on bridges on the electrified section of the Chicago, Milwaukee & St. Paul Railway Company in Montana. The tests on the Norfolk & Western Railway made in 1916 did not include spans exceeding 96 feet in length, and the speeds available did not exceed about 29 miles per hour. Those tests, therefore, while of very considerable value, did not have sufficient range to be as conclusive as might be desired. The results obtained were very satisfactory, so far as they went, and tended strongly to confirm the opinion previously expressed that impact under well-balanced electric locomotives would be very small. The value of the results of those tests was very considerably enhanced by making use on the same structure of two types of steam locomotives: the consolidation type and the Mallet type. The very great difference between the results obtained with the steam locomotives and with the electric locomotives, especially on the longer spans, was very significant as tending to show the relatively small impact from electric locomotives. However, the limited range of span length and the limited speed made it very desirable to continue the tests if possible on longer spans and at higher speeds. The very best conditions for such tests were to be obtained on the electrified lines of the Chicago, Milwaukee & St. Paul Railway Company in Montana, and a request by the Committee for the necessary facilities was promptly acceded to by this Company. The thanks of the Committee are due to the management of the Company, and particularly to Mr. C. F. Loweth, Chief Engineer, for the very excellent opportunities afforded the Committee for making these valuable tests.

CHARACTER OF STRUCTURES TESTED.

The structures tested consisted of the following types and span lengths:

First Crossing of Missoula River near Missoula, Mont.

- 60-ft. through girder.
- 80-ft. through girder.
- 100-ft. riveted pony truss.

Second Crossing of Missoula River near Cyr, Mont.

- 210-ft. deck truss.

Third Crossing of Missoula River near Cyr, Mont.

- 240-ft. deck truss.

Viaduct near Saltese, Mont.

62ft. and 46½-ft. span lengths.

The general dimensions and arrangements of these structures are shown in the figures given herein.

THE TEST LOAD.

The test load consisted of an electric locomotive composed of two units, followed by a sufficient number of loaded cars to cover the structure. A wheel load diagram of the locomotive is given herewith. The locomotive has its motors geared to the driving-wheel axles, no side rods being used in this type. All rotating parts are presumed to be balanced, so that any impact effect would be due to such causes as roughness of wheels and track and deflection of structure.

APPARATUS USED.

The apparatus used in these tests was the same as that used in previous tests made by the Committee. This is described in Bulletin 125, July, 1910. In addition to this apparatus, the Committee made use, to a small extent, of certain extensometers employed by Prof. A. N. Talbot in the track experiments which he is conducting on behalf of the Joint Committee established for the study of track stresses. These extensometers record directly, without multiplication, the strains in the members to which they are attached. The record is made by means of a fine steel point upon a smoked glass plate, and is read by means of a microscope. Such an apparatus has the advantage over the extensometer used by the Committee in that the difficulties due to instrumental vibration are avoided, which enables more satisfactory results to be obtained on very short-span girders. The quantities measured are, however, extremely small, and a considerable amount of experience is necessary before a reasonable degree of precision can be had. These instruments were used on a floor beam and on a short stringer. The results obtained on the floor beam indicated small impact, and tended to confirm the results obtained by the other type of extensometer which was applied to another beam of the same bridge. The results from the stringer indicated considerable impact, but many more observations would be necessary and much more experience with this type of apparatus before reliable results on the short spans could be secured. It is hoped that this field of experimentation can be adequately covered at some future time.

METHOD OF CONDUCTING TESTS.

The tests were made in the same general manner as those previously reported, namely, the special test train was run over the structure a considerable number of times at various rates of speed. Movements were made at low speeds of 8 to 12 miles per hour so as to secure readings not affected by impact. These readings were considered to represent static stresses, and the excess of stress resulting from movements at higher speeds was considered to represent the impact effect.

Speeds were readily obtained up to about 60 miles per hour and above. No tests were made with steam locomotives. It was thought that the very numerous experiments heretofore made with steam locomotives on structures of the kind herein described were sufficient to furnish a basis of comparison. The results of these tests, therefore, may be compared with the general results of those heretofore presented.

Results of Tests.

The important results of tests are given herewith in tabular form. The percentage of impact given is the maximum percentage obtained in the entire series of tests on each structure in question. A number of runs were made in each case at and near the highest speed indicated, and it is believed that the maximum percentages here given represent the maximum to be expected from the type of locomotive used. In fact, the actual percentage is probably somewhat less than the figures given, as the tendency of the extensometer is to exaggerate somewhat the percentage of impact for two reasons: First, because of the effect of friction in tending to show too small results, the error being greater at low speeds; second, the effect of inertia of the instrument, which tends to magnify the motion in case of vibrations.

IMPACT PERCENTAGES.

Structure.	*Maximum Impact Percentage.*
60 Ft. Through Plate Girder.	
7 Tests, maximum speed 63 m.p.h.	
Inside edge, top flange, north girder.........	5%
Outside edge, top flange, north girder.......	No impact at 50 m.p.h. Diagram imperfect at higher speeds.
Inside edge, top flange, south girder........	No impact at 42 m.p.h. Diagram imperfect at higher speeds.
Outside edge, top flange, south girder......	No impact up to 50 m.p.h. Diagram imperfect at higher speeds.
Deflectometer results	8½%
80 Ft. Through Plate Girder.	
15 Tests, maximum speed 61 m.p.h.	
Outside edge, top flange, north girder......	17%
Outside edge, top flange, south girder......	15%
Inside edge, top flange, south girder........	14%
Deflectometer results	15%
100 Ft. Span Pony Truss.	
19 Tests, maximum speed 68 m.p.h.	
Inside edge bottom flange, inclined end post.	5%
Inside edge, top flange, main diagonal.....	13%

	Records imperfect at high speeds.
Inside edge, top flange, top chord	23%
Outside edge, top flange, top chord	11%
Deflectometer results	9%

210 Ft. Deck Truss Span.

19 Tests, maximum speed 55 m.p.h.

Inside edge, main diagonal	9½%
Outside edge, main diagonal	11%
Inside edge, top flange, bottom chord	11%
Inside edge, bottom flange, end post	11%

240 Ft. Deck Truss Span.

12 Tests, maximum speed 60 m.p.h.

Outside edge, top flange, top chord	9%
West edge, bottom flange, 2nd floor beam from end	3%
East edge, bottom flange, 2nd floor beam from end	17%

Viaduct.

An effort was made to determine the effect of applying brakes to the train when crossing at a maximum speed of about 45 m.p.h. Seven tests were made. Instruments were attached to members as indicated in the sketch of the viaduct. The viaduct has a ballasted deck with reinforced concrete slab supports.

Vertical Post—The effect of applying brakes was to increase the stress in one flange about 6% and decrease the stress in the other flange about 4%.

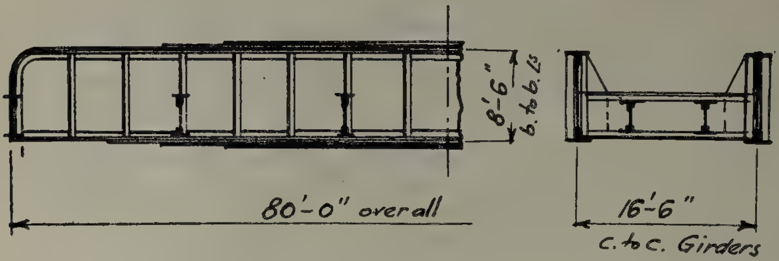
Diagonal Bracing—The stress in this diagonal bracing was not appreciably changed by the setting of brakes. The average stress for all runs was about 1,700 lbs. per sq. in. in one flange and 1,100 lbs. per sq. in. in the other.

It is apparent that the effect on the towers of applying brakes was scarcely appreciable.

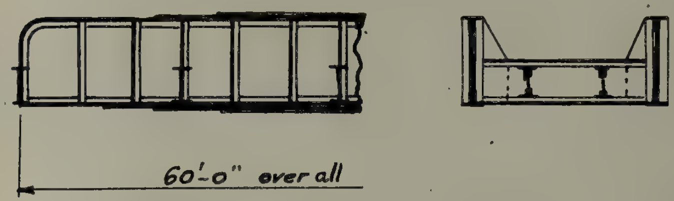
It will be seen, in general, that the impact effects were in most cases very small, and particularly so in the long truss spans. The relatively large impact of 23% in the top flange of the pony truss was probably due more to lateral movement than to vertical vibration. In the 60 ft. girder, instrumental vibration for speeds greater than about 50 miles per hour made the records valueless, but the results obtained for speeds below 50 miles per hour indicate that there was very little impact stress in the structure. The deflectometer readings are reliable.

CONCLUSIONS.

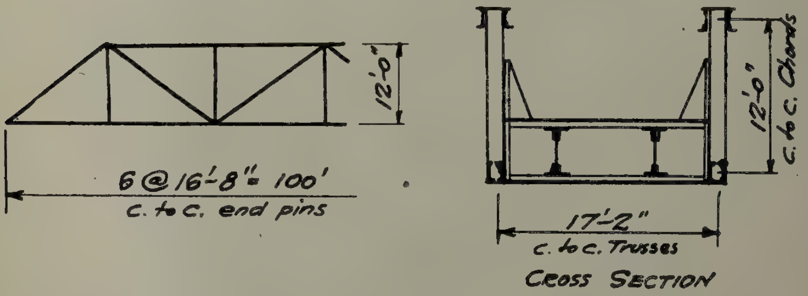
1. From the results of the tests on the electrified section of the Chicago, Milwaukee & St. Paul Railway, the tests made in 1916 on the Norfolk & Western Railway, and the few tests made in 1909 at Schenectady, New York, it would appear to be fairly well established that the impact effect from electric locomotives is very much less than from steam locomotives of the usual type. Comparing results obtained in these tests with the results from steam locomotives, it would appear that the impact from electric locomotives on structures exceeding, say, 25 ft. span length, is not more than one-third of the impact produced by steam locomotives.



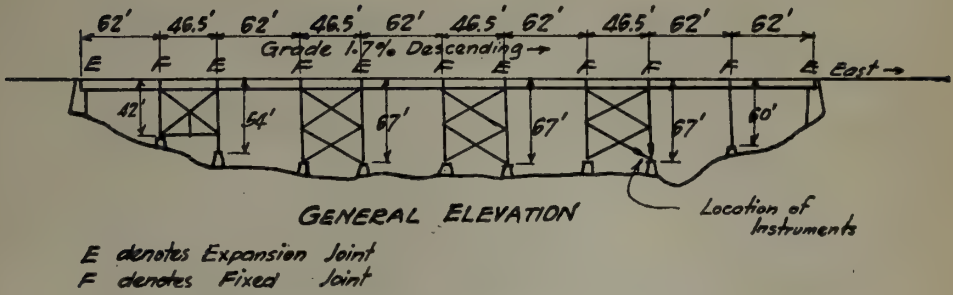
Chicago, Milwaukee & St. Paul Railway.
80-ft. Girder Span.
First Crossing of Missoula River near Missoula, Montana.



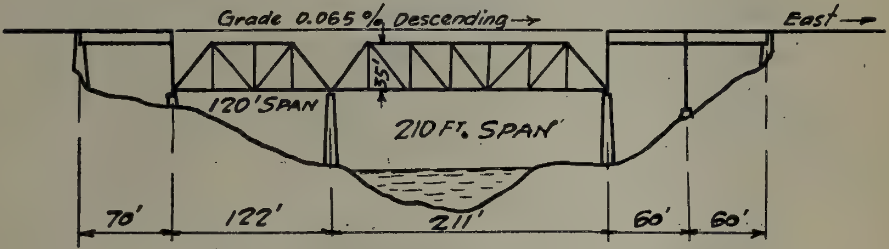
Chicago, Milwaukee & St. Paul Railway.
60-ft. Girder Span.
First Crossing of Missoula River near Missoula, Montana.



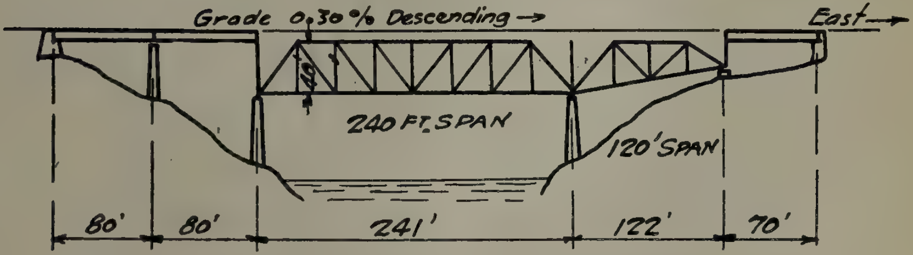
Chicago, Milwaukee & St. Paul Railway.
100-ft. Pony Truss Span.
First Crossing of Missoula River near Missoula, Montana.



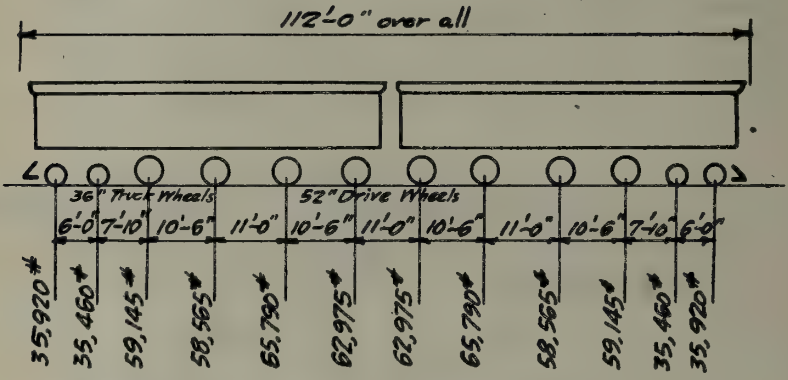
Chicago, Milwaukee & St. Paul Railway.
Silver Creek Viaduct, near Saltese, Montana.



Chicago, Milwaukee & St. Paul Railway.
210-ft. Deck Truss Span.
Second Crossing of Missoula River East of Cyr, Montana.



Chicago, Milwaukee & St. Paul Railway.
240-ft. Deck Truss Span.
Third Crossing of Missoula River West of Cyr, Montana.



Total Weight on Trucks	142,760#
Total Weight on Drivers	492,950#
Totol Weight of Locomotive	635,710#

CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.
ELECTRIC LOCOMOTIVE DIAGRAM.
Type 4-4-4—4-4-4, Class 10100-10111, Passenger Locomotive.

Appendix B.

COLUMN TESTS.

W. H. Moore, Chairman, Sub-Committee.

The program of column tests to be made by the Bureau of Standards for this Association was described fully in Vol. 16, p. 636.

Of the eight column sections which it was originally decided to have tested, only Column No. 1 of Series No. 1, consisting of two channels with flanges turned in, has been touched so far.

Complete reports of the tests of the first eighteen columns tested already have been published. (See American Railway Engineering Association Proceedings, Vol. 14, page 96; Vol. 15, page 435; Vol. 16, page 636, and inset at back of Volume, and Bulletin No. 173 for January, 1915.)

The present report covers tests of twenty-four columns made during 1916 by the Bureau of Standards under the direction of Dr. S. W. Stratton, to whom the hearty thanks of the Association are due. These columns are variations of Column No. 1, Series No. 1; the same general dimensions, area of cross-section, and slenderness ratios are used, the variations consisting of (1) changes in size of rivets and lacing bars; (2) the leaving off of wing and base plates; (3) the substitution of batten plates for lacing with varying distances between the batten plates.

The Bureau of Standards intended to supplement these tests by a series of compression tests of short specimens, cut from the channels of the columns, which tests were intended to bring out the reason why the columns made of thick material always fail at lower unit stresses than those made of thin material. It was hoped that these short compression tests could have been made during 1917, and, in fact, many of these tests have actually been made, but, owing to stress of other business, the Bureau has been unable to complete the series and to furnish the Committee with reports of the results. However, it may be stated that the short specimen tests show that, in compression, the thin material has a higher elastic strength than the thick material, although the original tensile specimen tests on which the material was accepted, gave practically identical results as regards the elastic limit in tension for the thick and the thin material. While the specimen tensile tests, in all cases, gave results reasonably close to the prescribed limits of 37,000 to 39,000 lbs. per sq. in., the short compressive tests showed yield points varying from below 30,000 lbs. per sq. in. to above 41,000 lbs. per sq. in.

This series of column tests proves, as have all the previous ones both for this Association and for the American Society of Civil Engineers, that the columns built of thin material almost invariably show higher unit stresses at failure than the similar columns built of thick material. The series also seems to show that, with lacing bars and rivets somewhat larger than standard practice calls for, the column will show additional strength.

As regards the substitution of batten plates instead of lacing bars, this series of tests shows conclusively that, in order to develop the full strength of the column, batten plates should not be used. It also shows that, where the distance from center to center of outer rivets on adjacent battens is fixed so that the 1/r distance for the individual channel is about the same as that for the column considered as a whole, the column is weaker than when this distance is reduced. In all cases, the columns with battens failed at an ultimate strength from 6000 to 9000 lbs. per sq. in. less than the corresponding column with lacing, and, in one case, the heavy section with 120 1/r, as much as 15,000 lbs. per sq. in. less.

In all cases, the length for computing the slenderness ratio of the column was taken as the entire length of the column, or the length between base plates, where base plates were used. When failure is emphasized by the complete visible destruction of the column, it usually becomes quite apparent that points of inflection occur not far from the ends of the column. This is less noticeable in the batten-plated columns, where the method of failure is usually by sudden bending at the batten plates.

Plate I shows details of Columns 1—I, —K, —L and —M.

Table No. 1 shows the make-up of Columns Nos. 1—G, —H, —I, —K, —L, —M, —N, and —O, and gives an abstract of the tests for the twenty-four columns of this series. Note the poor showing of the batten-plated columns and especially the extremely low value of the heavy section 1—M with $1/r = 120$.

Table No. 2 gives a comparison of the strength of columns of the first series and five columns in this series, the two columns of each pair differing in one detail, except Columns F and M, which differ in two.

Column 1—G is the same as Column 1—C of the first series except that the lacing is reduced from 2¼ in. by ⅜-inch to 2 in. by ¼-inch and the rivets are ⅝-inch diameter instead of ¾-inch.

Columns 1—N and 1—O are identical with 1—B and 1—E, respectively, of the first series, except that the sizes of the lacing and rivets are reduced the same as in Column 1—G.

Column 1—H is the same as Column 1—B of the first series except that in Column H the wing plates and base plates are left off.

From the comparisons in Table 2 of the three sets of columns which vary only in the sizes of the lacing bars and rivets, it would seem fair to assume that the heavier lacing and larger rivets add to the strength of the column.

Plate 1.

TABLE 1.

COLUMN TESTS
AMERICAN RAILWAY ENGINEERING ASSOCIATION

DEPT. OF COMMERCE
BUREAU OF STANDARDS, WASHINGTON. 1916.

TYPE NO.	TEST NO.	SECTION	L/r	BRACING	ULTIMATE STRENGTH	REMARKS	TYPE NO.	TEST NO.	SECTION	L/r	BRACING AND L/r FOR INDIVIDUAL L	ULTIMATE STRENGTH	REMARKS
1G	172			2"×1/4"	34214	*							
1G	173	[ ] LIGHT	120	SINGLE LATTICE	32000								
1G	174	Area=9.56□" 2-8"[16.25 lb		5/8" d.riv.	33000								
1H	191			2 1/4"×3/8"	33860	*	1K	184				27000	* Failed under load in about 3 mins.
1N	192			3/4" d.riv.	33870	Failed after 10 mins under load	1K	193			65.57	27823	Failed by deflecting south.
1H	197	[ ] LIGHT	85	SINGLE LATTICE	33850		1K	185	[ ] LIGHT	85	BATTEN	26 000	* Failed after 10 mins under load.
1N	199	Area=9.56□"		2"×1/4"	33623	* Sharp snapping at 28000#/□"	1I	186	Area=9.56□"			27000	*
1N	200	2-8"[16.25 lb.		5/8" d.riv.	33475		1I	190	2-8"[16.25 lb.		83.91	25142	Col. was failing steadily after application of 25000#/□" load and failed completely after 10 mins upon increasing load to ULTIMATE LOAD.
1N	204				34165		1I	198				23987	Failed suddenly by deflecting north.
1O	201			2"×1/4"	32100	*	1L	194				24199	Failed by deflecting north
1O	202	[ ] HEAVY	85	SINGLE LATTICE	31000		1L	195	[ ] HEAVY	85	BATTEN-80.73	23039	Failed by deflecting south
1O	203	Area=12.50□" 2-8"[21.25 lb.		5/8" d.riv.	32353	*	1L	196	Area=12.50□" 2-8"[21.25 lb.			24983	* Failed suddenly by deflecting north in center
							1M	187				15000	* Broke down under load in about 2 mins.
		[ ] HEAVY	120				1M	188	[ ] HEAVY	120	BATTEN-121.1	15200	Failed by deflecting between Batten plates.
		Area=12.50□" 2-8"[21.25 lb.					1M	189	Area=12.50□" 2-8"[21.25 lb.			15065	

* INDICATES THAT STRESS-STRAIN CURVES HAVE BEEN DRAWN
ULTIMATE STRENGTHS ARE GIVEN IN POUNDS PER SQ. INCH.

In the comparison between Columns B and H, with and without wing and base plates, the three B columns varied from 32,860 to 35,000 lbs. per sq. in., while the H columns varied only from 33,850 to 33,870 lbs. per sq. in. The greater uniformity in the H columns possibly is due to the superior accuracy of the bearings in the machine, these bearings having been scraped to exactly true and parallel surfaces by the Bureau. The ends of the channels in Column B, being inaccessible at the Bureau on account of the base plates, could not be made exactly true, but retained the slight inaccuracies incidental to the shop work.

Table No. 2.

Type No.	Area of Section, Sq.in.	1/r	Lacing & Rivets	Wing & Base Plates	Failure, lbs.per sq.in., mean of three tests
1 C	9.56	120	2 1/4" x 3/8" Rivets 3/4"	Yes	33,006
1 G	9.56	120	2" x 1/4" Rivets 5/8"	Yes	32,404
1 B	9.56	85	2 1/4" x 3/8" Rivets 3/4"	Yes	33,984
1 N	9.56	85	2" x 1/4" Rivets 5/8"	Yes	33,754
1 E	12.50	85	2 1/4" x 3/8" Rivets 3/4"	Yes	34,332
1 O	12.50	85	2" x 1/4" Rivets 5/8"	Yes	31,818
1 B	9.56	85	2 1/4" x 3/8" Rivets 3/4"	Yes	33,984
1 H	9.56	85	2 1/4"x 3/8" Rivets 3/4"	No	33,860
1 F	12.50	120	2 1/4" x 3/8" Rivets 3/4"	Yes	30, 809
1 M	12.50	120	Battens Rivets 3/4"	No	15,088

Column M is the same as Column F except that it has batten plates instead of lacing, and that the wing and base plates are omitted.

Plate II gives the stress strain diagrams for Columns H, L and M. On the last two, which are columns with batten plates, note that the stress strain line runs up straight to the point of ultimate strength and then fails without any transition curve.

Plate III shows photographs of Columns 1—G, —H, —I, —K, —L, and —M in the testing machine after failure had been emphasized.

The complete test records as furnished by the Bureau of Standards, together with stress-strain diagrams for Columns 1—G, —H, —N, —O, and 1—I, —K, —L, and —M similar to those published with the report on the first series of columns, have been bound and placed in the library of the Association, where they will be accessible for study. These reports, as well as giving the behavior of the column as a whole, furnish valuable information as to the distribution of local stresses shown by the 8-inch strain gage measurements.

CONCLUSIONS.

The conclusions that seem warranted from the tests so far made in the proposed series are:

(1) Columns in which batten plates are substituted for lacing bars will not develop the full strength of the section and should not be used.

(2) The specimen tensile tests on which material is ordered and accepted afford no proper criterion for the strength of a column.

(3) A column designed so that it fails as a whole and not by reason of local weakness will have an ultimate strength of which the compressive yield point of the material of which it is made up is an index, since the higher this yield point is, the stronger will be the column.

It will be desirable, and may be possible after the short specimen compressive tests are available for study, to add to the General Specifications a requirement covering short compressive tests.

In connection with the study of these tests, careful consideration should be given to the final report of the Committee on Steel Columns and Struts of the American Society of Civil Engineers published in the Proceedings of December, 1917. The "useful limit point" as therein defined should be noted and also the working stresses recommended for columns with square ends, these being 12,000 lbs. per sq. in. for slenderness ratios up to about 80 and dropping in a straight line from that point to 8000 lbs. per sq. in. at a slenderness ratio of 120.

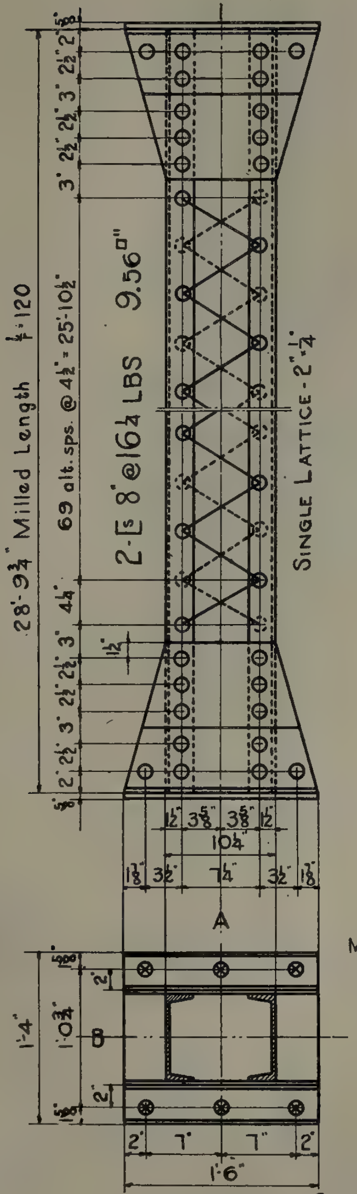
The program for the American Society of Civil Engineers was designed to eliminate all variables except form, slenderness ratio, and light and heavy material, and it excluded laced sections. The American Railway Engineering Association program, which was intended to supplement this, includes the ordinary forms generally found in bridge members, symmetrical laced sections and top chord sections balanced and unbalanced, certain of the sections to be tested with both square ends and pin ends. This program also contemplates the varying of details in the make-up of each form in the hope of indicating the best details, or at least those details which should be avoided.

The Committee had intended last spring, with the co-operation of Dr. S. W. Stratton and the Bureau of Standards, to proceed with another set of tests of variations on Column No. 1, arranging the tests so as to give eccentric loading of varying amounts of eccentricity on the series of columns, but this had to be abandoned on account of conditions arising out of the war.

Whenever it is possible to resume the tests, it will be interesting to ascertain the effect of using both thin and thick material in the same column. Columns Nos. 3 and 4 of the projected Series No. 1, which are laced columns built up of plates and angles, will be well suited for this purpose.

It is hoped that at some future date it may be possible to take up the work again and carry the program of tests to a conclusion.

Plate I.



RADII OF GYRATION

Axis B	Axis A
2.89	4.60

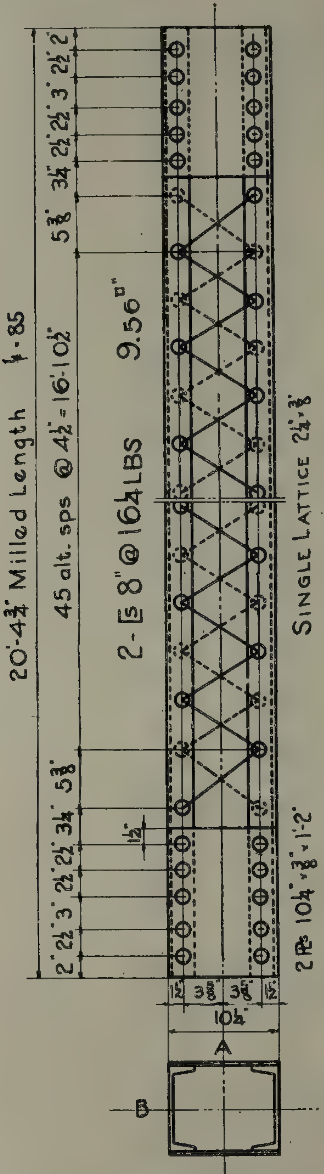
Material for base
1 Pl. 16" × ⅝" × 1'-6"
2 Pls. 14" × ⅜" × 1'-6"
2 Ls 6" × 3½" × ⅜" × 1'-6"

RIVETS ⅝" DIA.

COLUMN 1^G (172-3-4)

LIGHT SECTION

Plate I.



RADII OF GYRATION

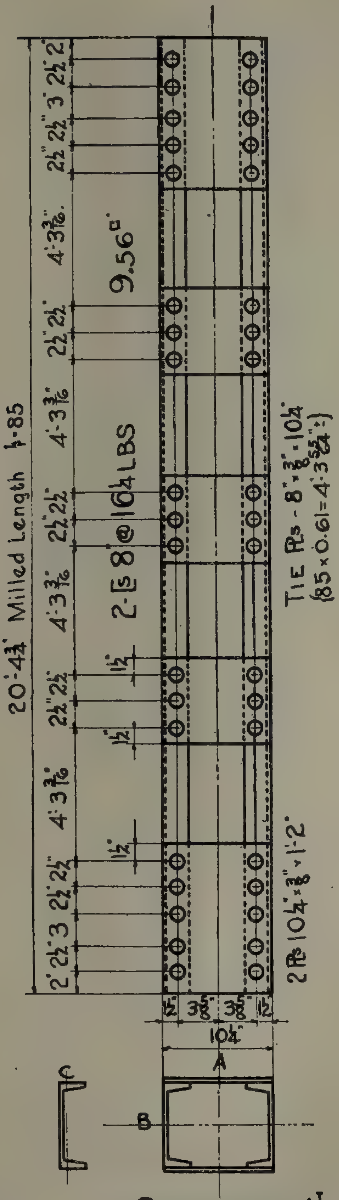
AXIS B	AXIS A
2.89	4.60

RIVETS ¾" DIA.

COLUMN 1H (191-192-197)

LIGHT SECTION

Plate I.



RADII OF GYRATION

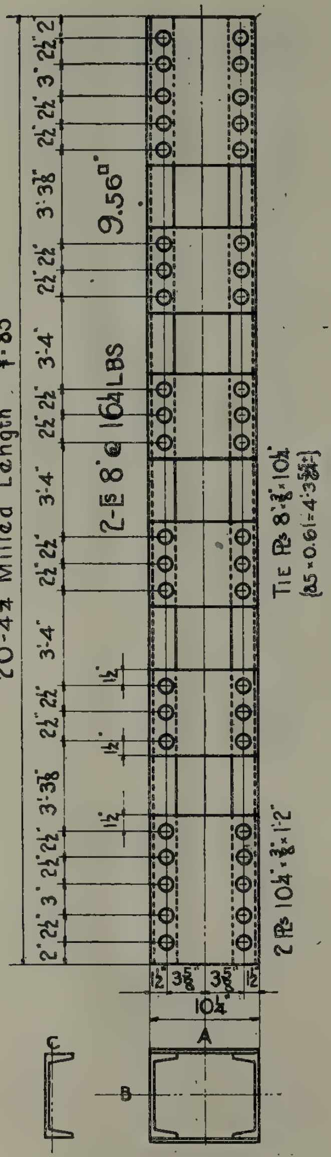
Total Section		[only
AXIS B	AXIS A	AXIS C
2.89	4.60	0.61

RIVETS ¾" DIA.

COLUMN 1^{I} (186-190-198)

LIGHT SECTION

Plate I.



RADII OF GYRATION

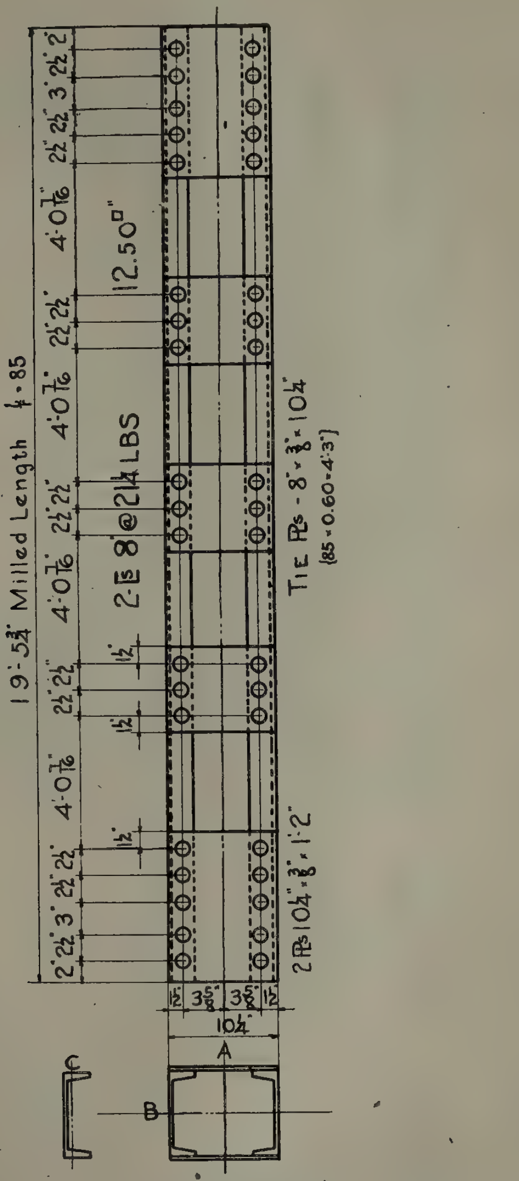
Total Section		⊏ only
Axis B	Axis A	Axis C
2.89	4.60	0.61

RIVETS ¾" DIA.

COLUMN 1K (184-193-185)

LIGHT SECTION

Plate I.



RADII OF GYRATION

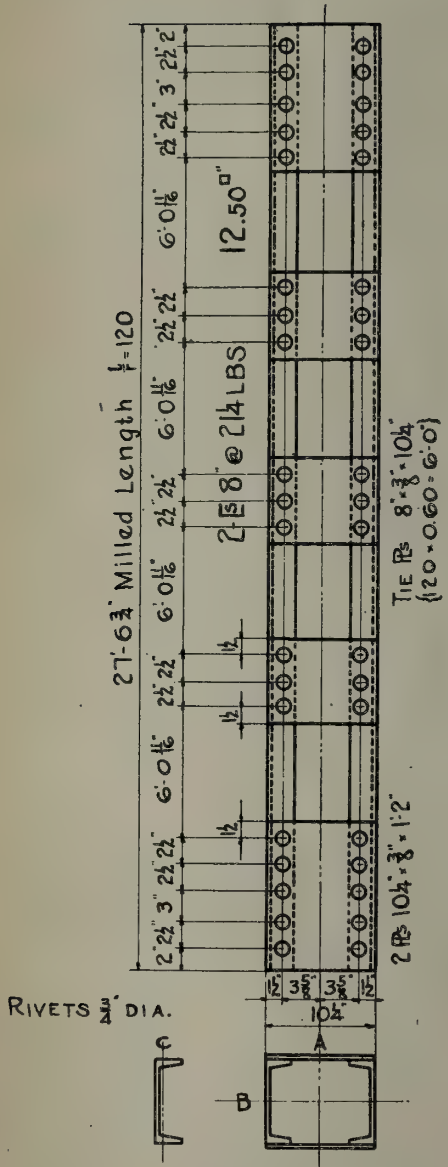
Total Section		[only
Axis B	Axis A	Axis C
2.77	4.57	0.60

RIVETS ¾" DIA.

COLUMN 1L (194-5-6)

HEAVY SECTION

Plate I.



Column 1^M

Heavy Section

Radii of Gyration

Total Section		[only
Axis B	Axis A	Axis C
2.77	4.57	0.60

Note—

Make 3 columns of each pattern making 18 columns in all.

Material and workmanship to be in accordance with the General Specifications for Steel Railroad Bridges of the American Railway Engineering Association.

(187-8-9)

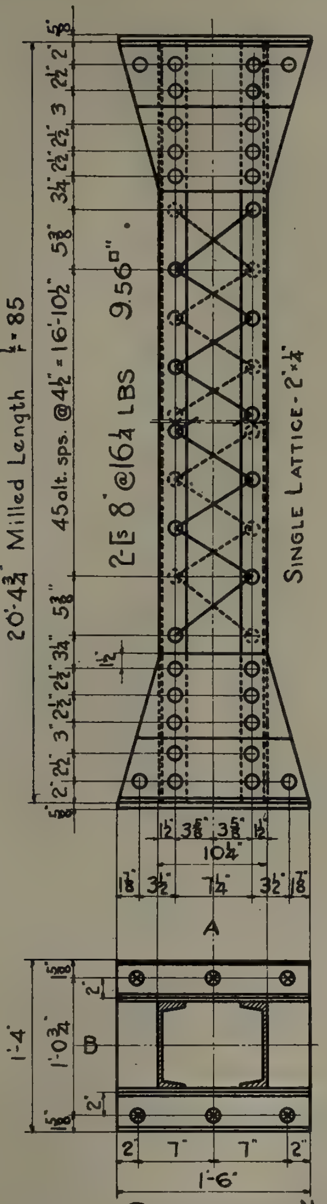
American Railway Engineering
Association.
-Column Tests-

Variations of Column No.1

Series No.1

March 1915
Revised June 1915

Plate I.



RADII OF GYRATION

Axis B	Axis A
2.89	4.60

Material for base.
1 Pl. 16" × ⅝" × 1'-6"
2 Pls. 14" × ⅜" × 1'-6"
2 Ls 6" × 3½" × ⅜" × 1'-6"

RIVETS ⅝" DIA.

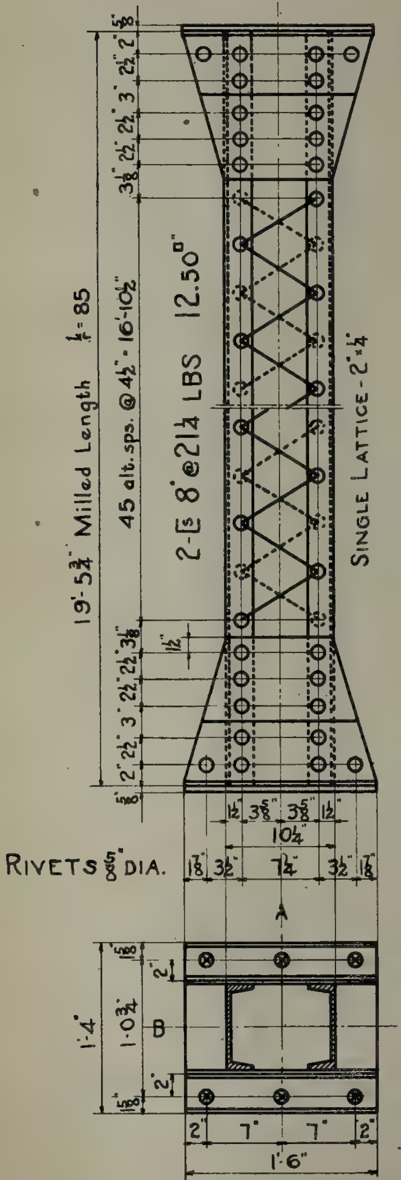
COLUMN 1^N (199-200-204)

LIGHT SECTION

Plate I.

RADII OF GYRATION

Axis B	Axis A
2.77	4.57



COLUMN 1°

HEAVY SECTION

Material for base
1 Pl 16" × ⅝" × 1'-6"
2 Pls 14" × ⅜" × 1'-6"
2 Ls 6" × 3½" × ⅜" × 1'-6"

NOTE—

Make 3 columns of each pattern making 6 columns in all.

Material and workmanship to be in accordance with the General Specifications for Steel Railroad Bridges of the American Railway Engineering Association.

(201-202-203)

AMERICAN RAILWAY ENGINEERING
ASSOCIATION
-COLUMN TESTS-
VARIATIONS OF COLUMN No.1 SERIES No.1
June 1915

Plate 11.

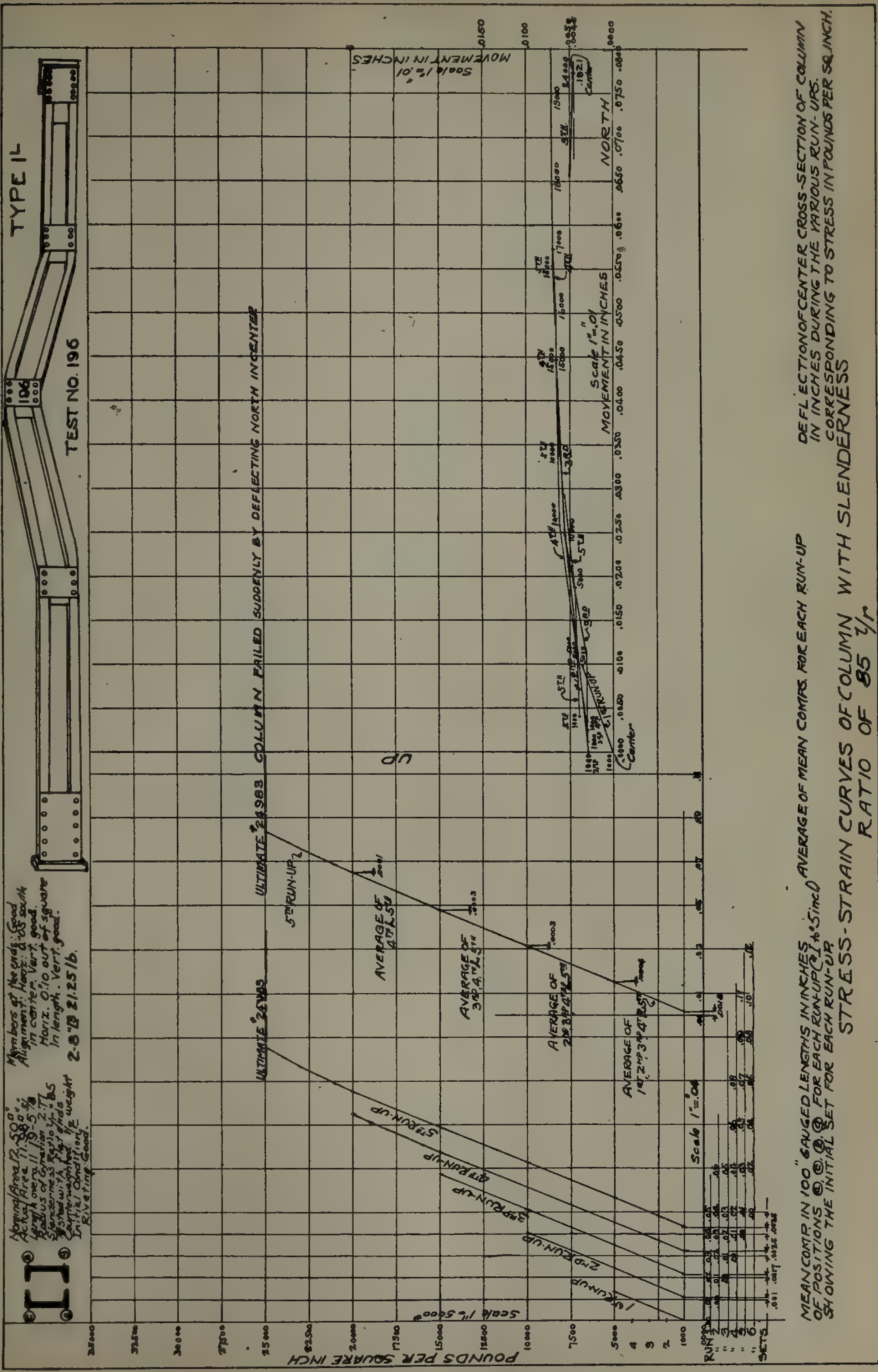
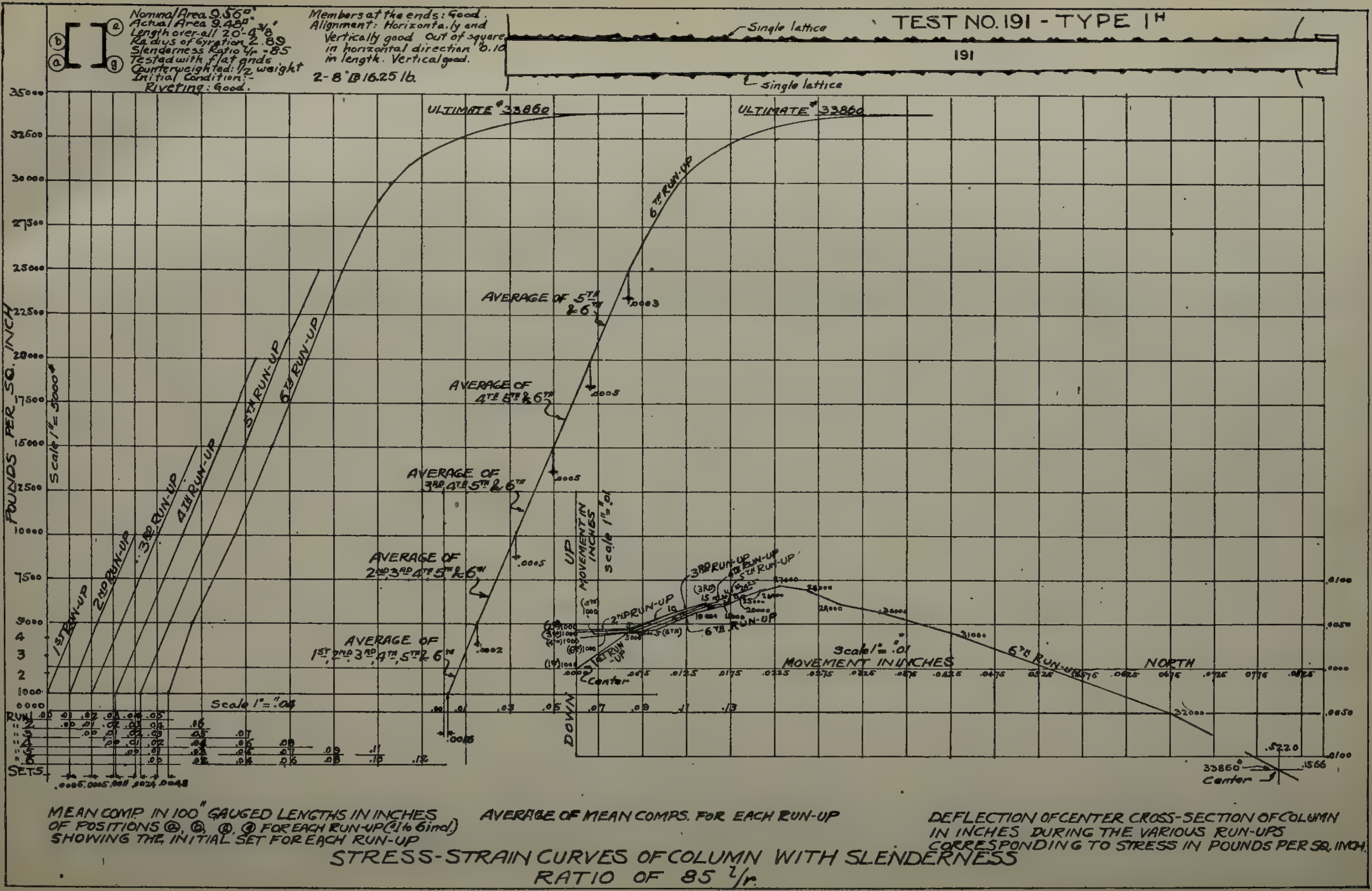

TYPE I^L
TEST NO. 196
196
Nominal Area 12.50□";
Actual Area 11.38□" 5%
Length over all 19-5 5/8
Radius of Gyration 2.71
Slenderness Ratio l/r = 85
Tested with flat ends
Center weighted 1/2 weight
Initial Condition;
Riveting. Good.
Members of the ends: Good
Alignment: Horiz: 0.03 south in center. Vert. good.
Horiz. 0.10 out of square in length. Vert. good.
2-8"⊏ 21.25 lb.
ULTIMATE 24983
COLUMN FAILED SUDDENLY BY DEFLECTING NORTH IN CENTER
ULTIMATE 24983
5TH RUN-UP
AVERAGE OF 4TH & 5TH
AVERAGE OF 3RD 4TH & 5TH
AVERAGE OF 2ND 3RD 4TH & 5TH
AVERAGE OF 1ST 2ND 3RD 4TH & 5TH
1ST RUN-UP
2ND RUN-UP
3RD RUN-UP
4TH RUN-UP
5TH RUN-UP
Scale 1" = 5000
Scale 1" = .04
UP
POUNDS PER SQUARE INCH
1000
5000
7500
10000
12500
15000
17500
20000
22500
25000
27500
30000
32500
35000
RUN 1
" 2
" 3
" 4
" 5
SETS
NORTH
Scale 1" = .01
MOVEMENT IN INCHES
Center
.0000 .0050 .0100 .0150 .0200 .0250 .0300 .0350 .0400 .0450 .0500 .0550 .0600 .0650 .0700 .0750 .0800
Scale 1" = .01
MOVEMENT IN INCHES
.0000
.0050
.0100
.0150
MEAN COMP. IN 100" GAUGED LENGTHS IN INCHES OF POSITIONS ①, ②, ③ & ④ FOR EACH RUN-UP (2 1/2 to 5 inc.) SHOWING THE INITIAL SET FOR EACH RUN-UP
AVERAGE OF MEAN COMPS. FOR EACH RUN-UP
DEFLECTION OF CENTER CROSS-SECTION OF COLUMN IN INCHES DURING THE VARIOUS RUN-UPS. CORRESPONDING TO STRESS IN POUNDS PER SQ. INCH.
STRESS-STRAIN CURVES OF COLUMN WITH SLENDERNESS RATIO OF 85 l/r

Plate 11.



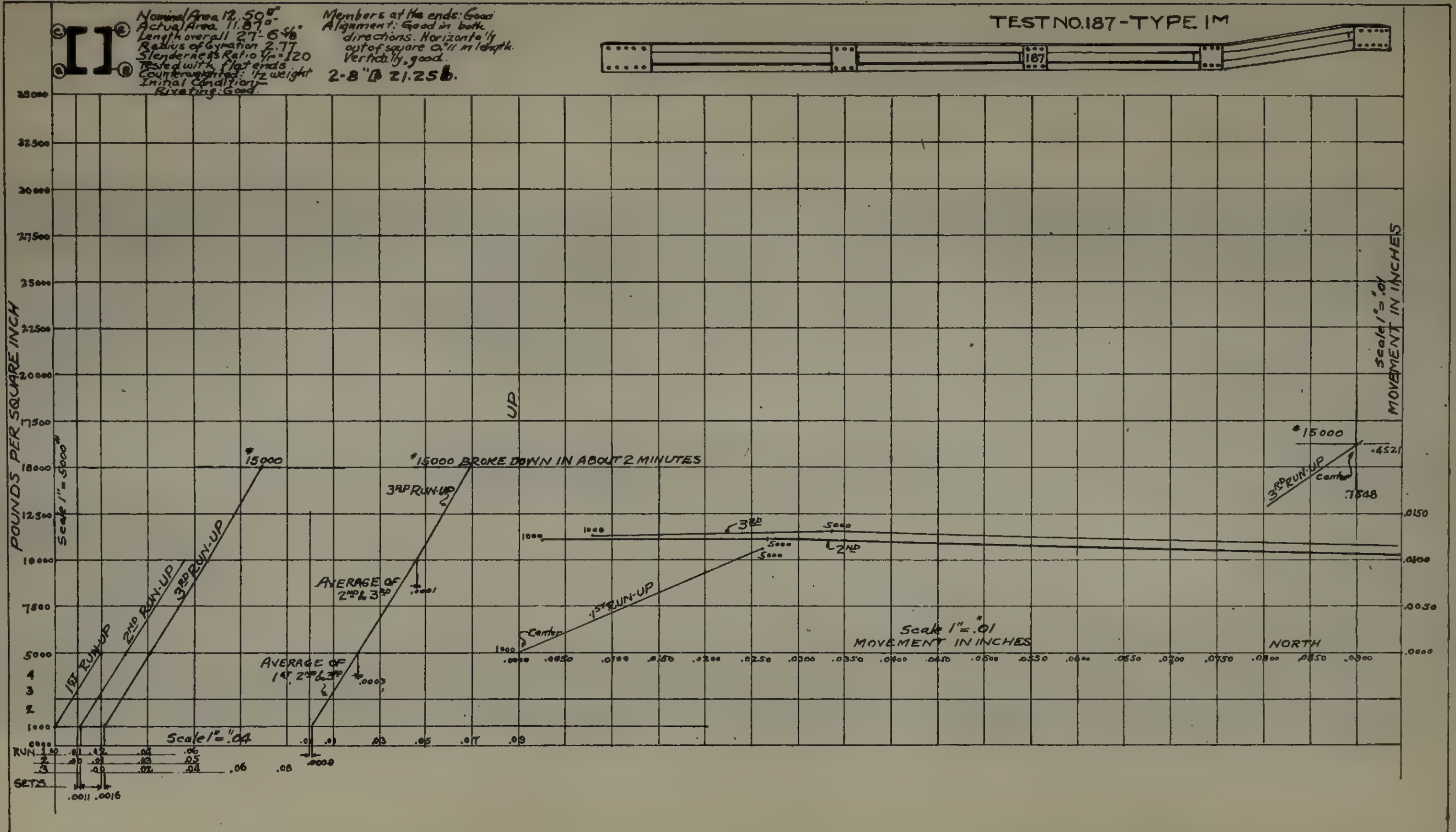
MEAN COMP. IN 100" GAUGED LENGTHS IN INCHES OF POSITIONS ⓐ, ⓑ, ⓔ, ⓖ FOR EACH RUN-UP (1 to 6 incl.) SHOWING THE INITIAL SET FOR EACH RUN-UP

AVERAGE OF MEAN COMPS. FOR EACH RUN-UP

DEFLECTION OF CENTER CROSS-SECTION OF COLUMN IN INCHES DURING THE VARIOUS RUN-UPS CORRESPONDING TO STRESS IN POUNDS PER SQ. INCH.

STRESS-STRAIN CURVES OF COLUMN WITH SLENDERNESS RATIO OF 85 l/r.

Plate II.



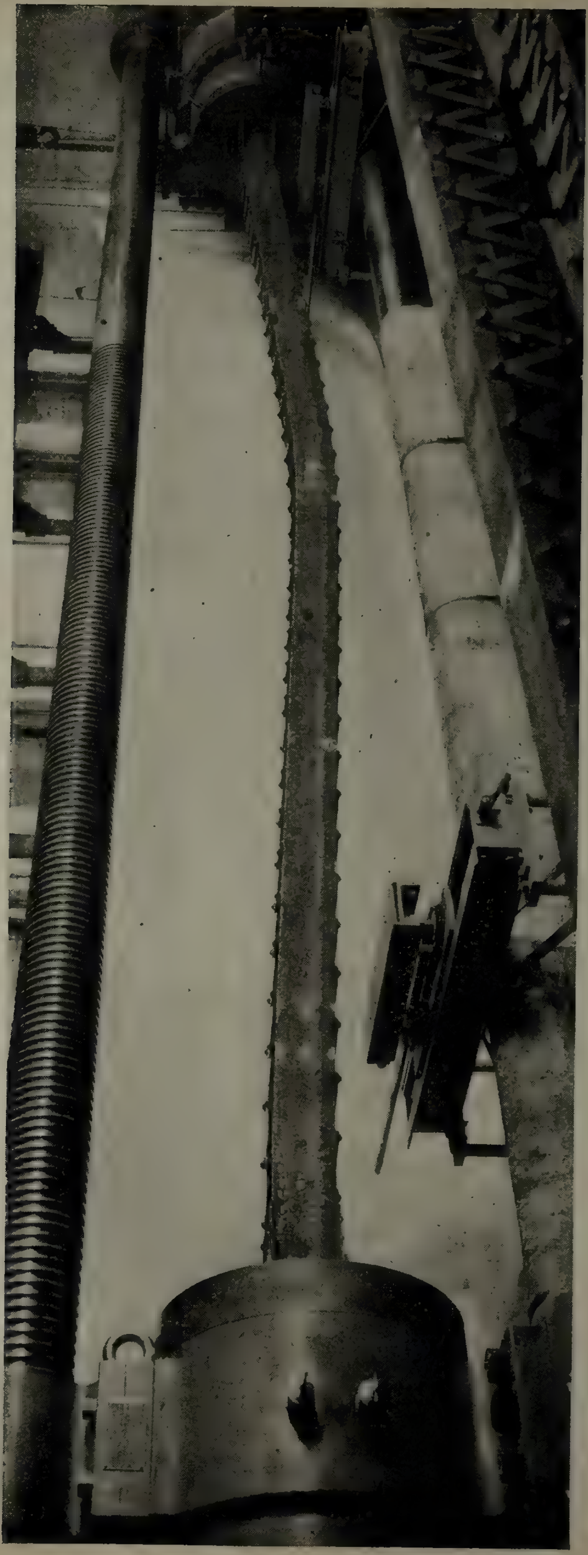
MEAN COMP. IN 150" GAUGED LENGTHS IN INCHES OF POSITIONS ⓐ, ⓒ, ⓓ, ⓑ. FOR EACH RUN-UP (#1 to #3 incl.) SHOWING THE INITIAL SET FOR EACH RUN-UP.

AVERAGE OF MEAN COMPS. FOR EACH RUN-UP

DEFLECTION OF CENTER CROSS-SECTION OF COLUMN IN INCHES DURING THE VARIOUS RUN-UPS CORRESPONDING TO STRESS IN POUNDS PER SQ. INCH.

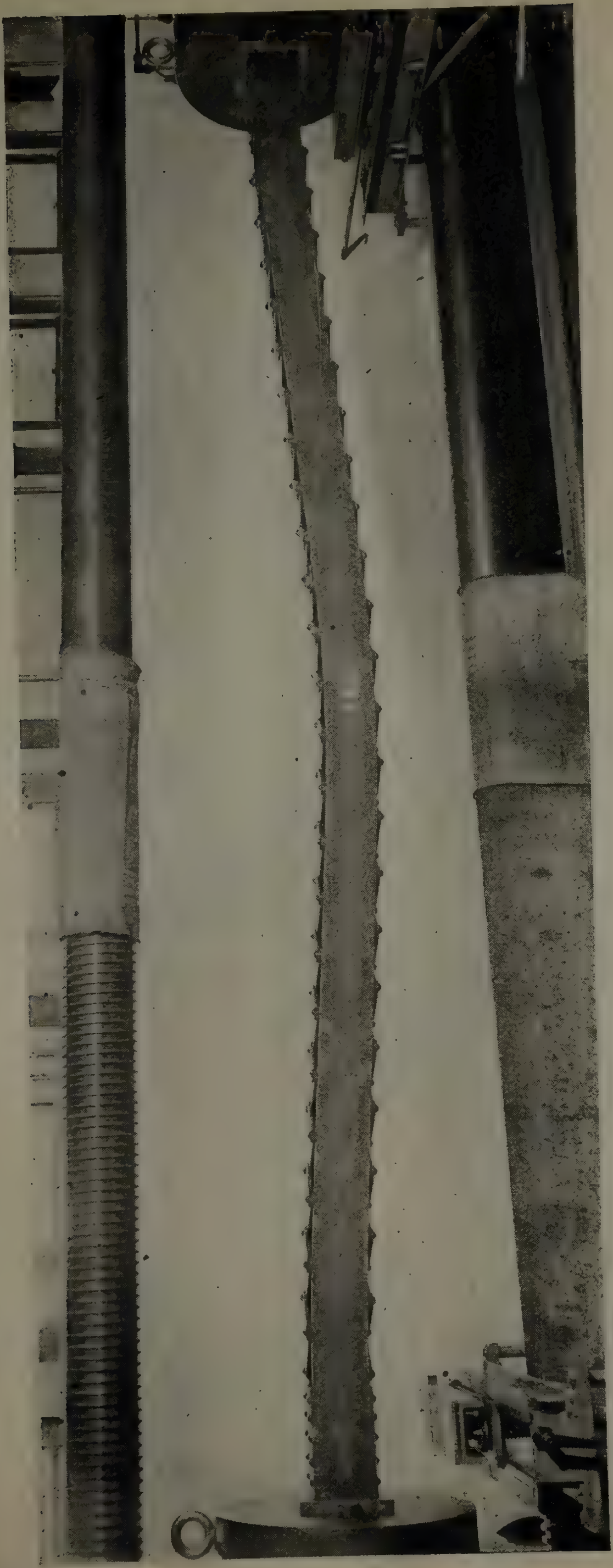
STRESS-STRAIN CURVES OF COLUMN WITH SLENDERNESS RATIO OF 120 l/r

Plate III.



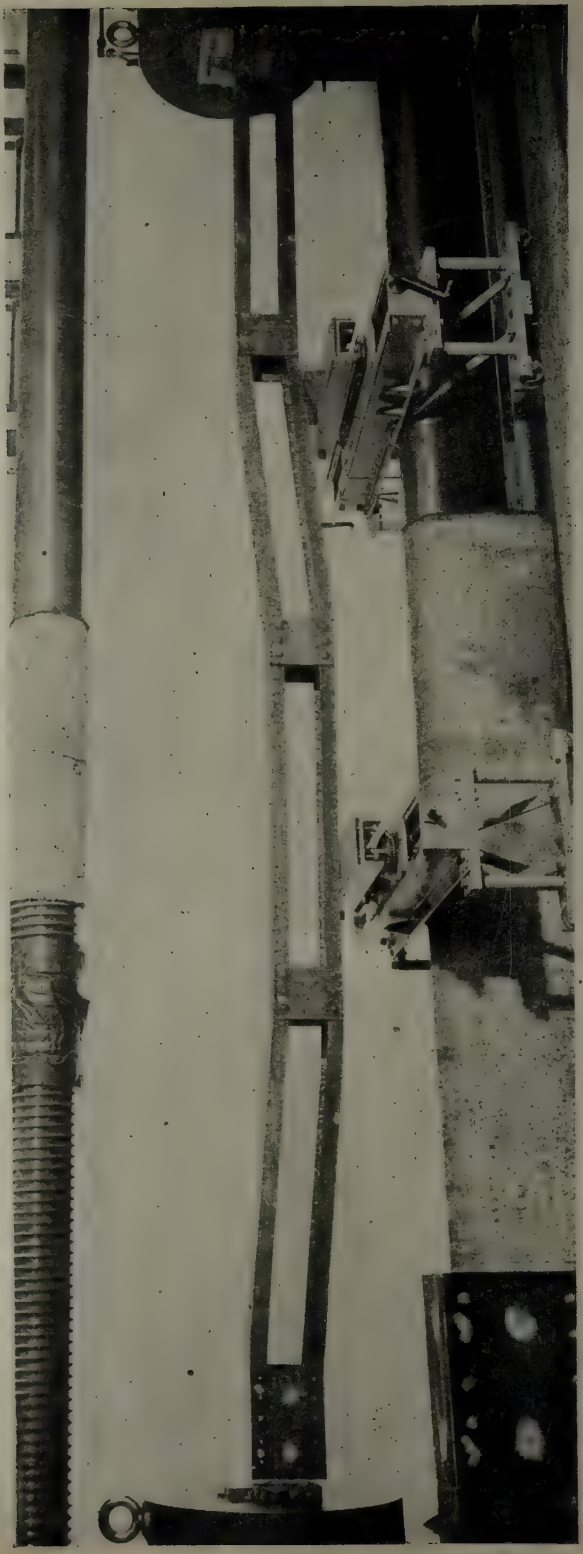
Column 1-G.

Plate III.



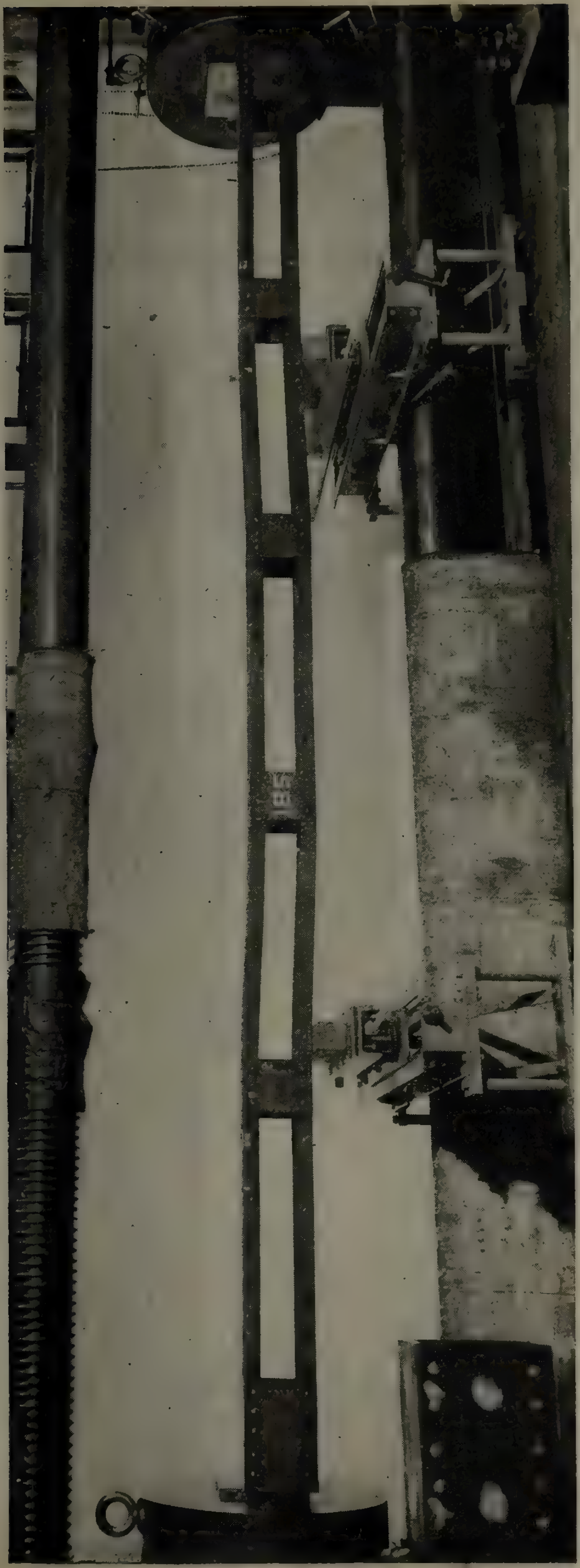
COLUMN 1-H.

Plate III.



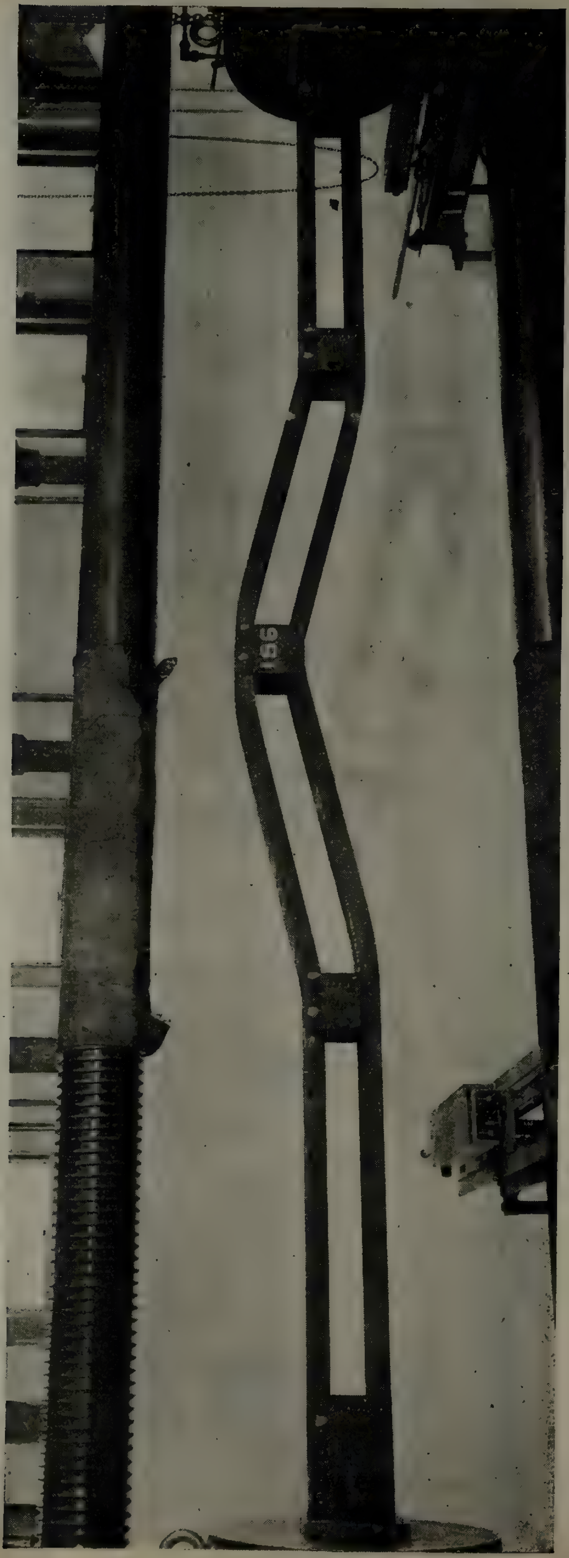
Column 1-I.

Plate III.



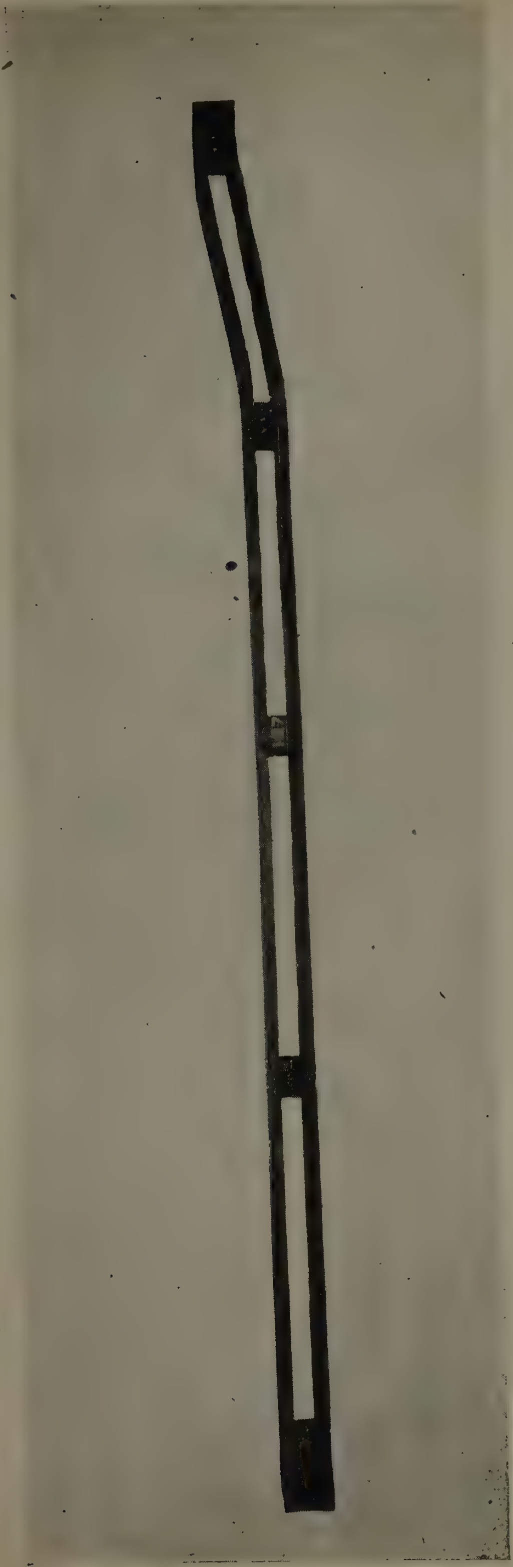
Column 1-K.

Plate III.



COLUMN 1-L

Plate III.



Column 1-M.

Appendix C.

SPECIFICATIONS FOR BRONZE BEARING METALS FOR TURNTABLES AND MOVABLE RAILROAD BRIDGES.

W. S. Bouton, Chairman, Sub-Committee.

1. Phosphor bronze shall be a homogeneous alloy of crystalline structure. It shall be made from new metals, except that scrap of known composition produced by the foundry at which the bronze is cast may be used. It shall not contain sulphur. The phosphorus shall be introduced in the form of phosphor-tin or phosphor-copper. Castings shall be sound, clean, and free from blowholes, porous places, cracks and other defects.

2. The alloy shall be cast into ingots and allowed to cool, and the castings shall be poured from the remelted ingots. Care shall be exercised that the metal is not overheated and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

3. There shall be four grades:

Grade A is to be used for contact with hardened steel discs under pressures exceeding 1500 lbs. per sq. in., such as are used in turntables and center bearing swing bridges.

Grade B is to be used for contact with soft steel at low speeds under pressures not exceeding 1500 lbs. per sq. in., such as trunnions and journals of bascule and lift bridges.

Grade C is to be used for ordinary machinery bearings.

Grade D is to be used for gears, worm wheels, nuts, and similar parts which are subjected to other than compressive stresses.

4. The chemical and physical qualities shall conform with the requirements in the table on the following page.

5. The chemical analysis of each heat shall be furnished.

6. Test specimens shall be made from coupons which are a part of the casting and which have been fed and cooled under the same conditions as the casting.

7. Compression test specimens shall be cylinders one inch high and of one square inch area. The elastic limit in compression shall be the load which gives a permanent set of 0.001 inch.

8. Tension test specimens shall be turned from a coupon not less than one inch in diameter to the form shown in Fig. 2 of the American Railway Engineering Association, General Specifications for Steel Railway Bridges. The diameter of the turned specimen shall be one-half inch.

9. At least one compression test shall be made from each melt for grades A, B, and C; and one compression and one tension test for grade D. For castings weighing over 100 lbs., finished, the prescribed tests shall be made for each casting.

10. The hardness of the finished castings shall be tested by the Brinell ball method and a record of the test furnished. The ball shall be of hardened steel 10 mm. in diameter. The load shall be 500 kg. and shall be applied for 30 seconds to a finished plane surface. At least two hardness tests shall be made upon each heat. A test shall be made on each trunnion bearing and each disc.

CHEMICAL AND PHYSICAL QUALITIES.

	GRADE			
	A	B	C	D
Alloy of	Copper and tin	Copper and tin	Copper, tin and lead	Copper, tin and zinc
Copper per cent			82 max.	89 max.
Tin per cent.	20 max.	17 max.	11 max.	11 max.
Lead per cent.			11 max.	
Zinc per cent.				2.25 max.
Phosphorus per cent.	1.0 max.	1.0 max.	1.0 max. 0.7 min.	0.25 max.
Other elements per cent.	0.5 max.	0.5 max.	0.5 max.	0.5 max.
Elastic limit in compression, pounds per square inch	24000 min.	18000 min.		
Permanent set under 100,000 pounds	.06 min. .10 max.	.10 min. .20 max.		
Permanent set under 50,000 pounds	To be recorded	To be recorded	To be recorded	To be recorded
Yield point in tension, pounds per square inch				To be recorded
Ultimate strength in tension, pounds per sq. in.				33000 min.
Elongation in 2 inches per cent.				14 min.

Cracks or other evidence of excessive brittleness in compression test specimens after load may be cause for rejection.

Appendix D.

SPECIFICATIONS FOR MOVABLE BRIDGES.

1918.

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Information to Be Given Bidders.

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SPECIFICATIONS FOR MOVABLE BRIDGES.

1. PROPOSALS AND GENERAL REQUIREMENTS.

101. The General Specifications for Steel Railway Bridges of the American Railway Engineering Association shall apply to movable bridges except as modified herein.

Responsibility.

102. Unless otherwise provided, the fabricating contractor shall be responsible for the complete installation of the superstructure and the operation of the moving span as far as pertains to the materials, workmanship, and erection, and the designing of parts and details which are not covered by the proposal plans. The Contractor shall furnish and erect the structure ready for the application of power for its operation and to receive trains. The Contractor shall be governed by the requirements of both the specifications and the proposal plans.

Time of Opening.

103. The normal time for opening the bridge after the ends are released shall be as specified on the proposal drawings for both the main and auxiliary powers.

Machinery Drawings.

104. The Contractor shall furnish an outline drawing of the machinery on which are shown the forces acting on the gear teeth, the twisting moment and the bending moment on shafts, and other information necessary for computing the strength of the machinery parts. The Contractor shall make an assembly drawing and complete detail drawings of the machinery. These drawings shall be so complete that the machinery parts may be duplicated without reference to patterns, other drawings, or individual shop practice.

Torque Curves.

105. The Contractor shall show by curves the torque to be exerted by the motor, as follows:

a. Torque curves for acceleration and for retardation.

b. A torque curve for the frictional resistance. The torque for starting friction shall not be combined with the torque for acceleration.

c. A torque curve for any unbalanced condition of the structure.

d. A torque curve for the wind loads.

e. A torque curve showing the greatest combination of resistances acting at one time. The torque curves of the motors under various operating conditions shall be superimposed on the curve.

Center of Gravity.

106. The Contractor shall compute the location of the center of gravity of the moving span, including parts attached thereto, and of the

counterweights and counterweight girders and trusses. These computations shall be based on accurate weights computed from shop plans. Duplicate copies of these computations, accompanied by weight bills, shall be submitted to the Company for approval.

Houses.

107. The Contractor shall furnish and build the machinery house. The house for the operator and for the signal devices shall be built by the Contractor or the Company as may be stipulated.

Signals and Interlocking.

108. The Company will furnish and install the railway signal system, including the master lever and the devices necessary for the interlocking between the signal system and the moving span. The Contractor shall furnish and install the devices necessary for interlocking the parts of the bridge machinery with each other and for connection to the Company's master lever. The operating machinery and electrical parts shall be designed so that the signal system may readily be attached and installed.

Warning Lights.

109. The Contractor shall make provision (including wiring) for installing on the moving span, the warning lights and other signals required by the United States Government or other authorities, and shall provide suitable means of access to such lights. The Contractor shall furnish these lights.

Wrenches.

110. Wrenches to fit the heads and nuts of bolts shall be furnished by the Contractor.

Defects,

111. If any defects due to faulty workmanship, or erection, or defective material, or design for which the Contractor is responsible are found within one year after the final test and acceptance, the Contractor shall remedy such defects at his own cost. If necessary, the Company may remedy such defects at the expense of the Contractor.

Classification of Parts.

112. The parts of the bridge shall be classified as follows, and unless otherwise stipulated, paid for in the manner indicated:

a. Structural Steel, by the pound.
b. Machinery, by the pound.
c. Engines, by a lump sum.
d. Boilers and tanks, by a lump sum.
e. Electrical equipment, by a lump sum.
f. Houses for machinery and for operators, by a lump sum.
g. Wire ropes, by the pound.
h. Wire rope attachments, by the pound.
i. Sheaves for counterweights, by the pound.
j. Metal in counterweights, by the pound.

k. Concrete, by the cubic yard.
l. Timber deck and track, by the linear foot of track.
m. Timber walks, by the thousand feet, board measure.
n. Balancing chains, by the pound.

Parts not classified under headings b to n inclusive, shall be classified under a, structural steel.

113. The parts included in the various classifications shall be:

a. *Structural Steel.* In addition to the moving span, any rolled or cast steel parts which can be fabricated by the common shop methods of punching, reaming, drilling, boring, shearing, planing, bending, etc., usual for stationary structures.

Rim girders in swing bridges, segmental girders in rolling bascule bridges and the girders on which they roll, tread plates in rolling bascule bridges, pedestals, wedge bases, center pivot stands, parts supporting the machinery, counterweight frames, counterweight trusses, operating struts, towers, steel framing and plates in houses for machinery and operators, hand rails, stairways, ladders, and specially fabricated track rails shall be classified as structural steel.

b. *Machinery.* Drums, pistons and their cylinders, eccentrics, pivots, trunnions and their cast supports, shafting, spools, gear wheels, racks, boxes, bearings, couplings, clutches, brakes (unless part of the motors), discs, cast sheaves and wheels, rollers, cast roller treads and guides, worm gearing, valves, pins about whose axes the connecting members rotate, screws, wedges, toggles, bridge locks, rail locks, indicators, whistles, cranks, axles, hooks, wrenches, and similar parts which require machine shop work and which are not included in any other classification herein. Machinery parts attached to structural parts shall be weighed separately.

c. *Engines.* Internal combustion engines, steam engines, pumps and compressors.

d. *Boilers and Tanks.* Steam boilers and stacks, air compressor tanks and other tanks with their fittings and piping.

e. *Electrical Equipment.* The switchboard with its attachments and electrical parts beyond, whether on or off of the moving span, such as conductors, conduits and their fittings, controllers, lamps, blow-outs, cut-offs, circuit breakers, contactors, solenoids, switches, motors, trolley poles, trolley wheels and contact shoes.

Electrical equipment carrying the current to the switchboard from the source of power will be covered by a separate contract.

f. *Houses for Machinery and Operators.* All parts of such houses except steel framing and plates.

g. *Wire Ropes.* The ropes with their attached sockets.

h. *Wire Rope Attachments.* Fastenings of the ropes to the trusses and counterweights, including pins and equalizing devices.

i. *Counterweight Sheaves.* Cast, or built sheaves, together with their axles and bearings.

j. *Metal in Counterweights.* Only cast iron and scrap metal used in counterweights.

k. *Concrete.* Concrete and reinforcing bars used in counterweights, and concrete in pockets of column bases and similar places.

In computing the volume of the concrete, all metal, except the reinforcing bars, shall be excluded.

l. *Timber Deck and Track.* Placing and permanently fastening the timber deck and track. Unless otherwise specified the Company will furnish the deck and track material and fastenings except rail-locks, specially fabricated rails, and special devices to hold the deck in place.

m. *Timber Walks.* Furnishing and placing lumber in walks, platforms, etc., together with nails, bolts, and other fastenings.

n. *Balancing Chains.* Chains and their fastenings used for balancing the counterweight ropes.

2. GENERAL FEATURES OF DESIGN.

Types.

201. Movable bridges preferably shall be of one of the following types:

a. Swing Bridges.
b. Single Leaf Bascule Bridges.
c. Vertical Lift Bridges.

The type to be used will be determined by the Engineer. Pin connected trusses shall not be used.

Counterweight.

202. The counterweight shall be sufficient to balance the moving span and its attachments in any position. In vertical lift bridges, the counterweight ropes shall be balanced by chains unless otherwise specified.

Alining and Locking.

203. Movable bridges shall be equipped with proper mechanism to aline them accurately and lock them securely in position so that they cannot be displaced either horizontally or vertically under the action of traffic. The operating mechanisms of end lifts of swing bridges and rail locks shall be independent.

Auxiliary Power.

204. Bridges equipped with mechanical power shall be provided with auxiliary power which shall be hand or mechanical, as determined by the Engineer.

Interlocking.

205. The bridge operating functions shall be interlocked with the signal system in such a manner that none of the functions for opening the bridge can be performed until the signals have been set at stop indication, and that the signals cannot be set at proceed indication until all of the functions for closing the bridge have been performed.

The bridge operating functions shall be interlocked with each other in such a manner that they must be performed in a predetermined order for both opening and closing the bridge.

Insulation of Track.

206. The connections of parts in contact with the track shall be such as not to allow short circuiting of track signals.

Houses for Machinery and Operators.

207. If mechanical power is to be used for operating the bridge, a suitable house shall be provided for the machinery. The house shall be fireproof and weatherproof. Except for the doors and windows, the material of the house shall be metal and concrete. There shall be at least one window in each side of the house. The machinery shall be supported by a rigid construction of metal.

The floor shall be built of concrete. It shall be smoke tight and have a non-slip surface.

If the operator is not located in the machinery house, or if the bridge is hand operated, a house shall be provided for him. The style of construction shall be the same as stipulated for the machinery house, except that for hand operation when the house is located off the bridge structure, fully fireproof construction will not be required.

Provision shall be made for the heating apparatus to be installed by the Company in the operator's house.

If stipulated, a 5-ton capacity hand-operated overhead traveling crane shall be installed in the machinery house.

Stairways and Walks.

208. Metal stairways, platforms, and walks with railings shall be provided, for access to the operator's house, machinery, trunnions, counterweights, lights, bridge seats, and similar parts. Ladders may be installed only where stairways are not feasible. In vertical lift bridges, ladders and walks to give access between the moving span in any position and one tower shall be installed. Hand railings shall be made of 1½ inch gas pipe. Stairways and ladders shall be of metal.

Materials Used.

209. Materials shall be used in machinery and similar parts as follows:

Rolled Steel or Forged Steel; for bolts, nuts, keys, cotters, pins, axles, shafts, screws, worms, piston rods, trunnions, and crane hooks.

For shafts up to 6 inches in diameter, the steel may be either rolled or forged; for shafts larger than this, it shall be forged. Shafts larger than 3½ inches in diameter shall not be cold rolled.

Forged Steel or Cast Steel; for levers, cranks, connecting rods and rollers.

Forged Steel; for pinions and equalizing levers.

Cast Steel; for pivot stands, couplings, wedges, wedge bearings, trailing wheels, end shoes, racks, tracks, gear wheels, brake wheels, sheaves on lift bridges, trunnion bearings, and shaft bearings and hangers. Large sheaves may be built of structural steel and cast steel.

Tool Steel; for parts which require hardening or oil tempering, such as pivots, friction rollers, ball bearings, and springs.

Phosphor-bronze; for pivot discs, worm wheels, linings of the trunnion bearings of bascule and lift bridges, linings of other large bearings carrying heavy loads, and such gears and nuts as are required to be of bronze.

Phosphor-bronze, Bronze, or Babbitt Metal; for the linings of journal bearings and of other rotating or sliding parts.

Cast Iron may be used for eccentrics, cylinders, pistons, fly-wheels, certain shaft bearings described below, journal boxes, and parts of motors which are usually made of cast iron. In power operated bridges, the permission to use cast iron shaft bearings applies only to line shaft bearings carrying the weight of the shafting only. Cast iron shall not be used for couplings, for any trunnion support of a bascule or lift bridge, or in the pivot of a swing bridge.

The balancing chains, which are hung below the counterweights in vertical lift bridges, shall be made of cast iron links connected by steel pins in cored holes.

Style of Center.

210. The style of the center to be used in swing bridges will be determined by the Engineer,

Center-bearing.

211. Center-bearing swing bridges shall be designed so that when the bridge is swinging, the entire weight of the moving span is carried on a center pivot, and when the bridge is closed, the trusses rest at the center on wedges.

Rim-bearing.

212. The load of a rim-bearing or combined rim- and center-bearing swing bridge coming on the rim girder shall be distributed equally among the bearing points. The bearing points shall be equally spaced around the rim.

Combined Bearing.

213. In a combined rim- and center-bearing swing bridge, a definite portion of the load, not less than 15 per cent., shall be carried to the center by radial girders attached rigidly to the center and to the rim.

Shear Over Center.

214. In swing bridges having a center truss-panel, this panel shall be designed not to carry shear past the center.

3. DETAILS OF DESIGN.

Rail End Connections.

301. Designs for rail end connections will be furnished by the Engineer. If the connections are of the sliding rail lock type, the ends of the bridge rails shall be fixed, cut square, and connected with the approach rails by sliding sleeves or joint bars, to carry the wheels over the openings between the rail ends. The distance from the center of

the track to the inside of the rail lock wheel tread shall be not less than 2 feet 6 inches, and not more than 2 feet 6½ inches, the heads of the rails being planed off on the outside if necessary. At the counterweight end of bascule bridges, the sliding locks shall be on the approach. Sliding rail locks, if power operated, shall have not less than 2½ horse power per track for each end of the bridge.

Rim Girders.

302. Rim girders shall be provided with stiffeners with fillers on both sides of the web at points of concentrated loading. These stiffeners shall fit closely against both flanges. Intermediate stiffeners shall be placed at distances apart not exceeding two feet. On rim girders exceeding five feet in depth, alternate intermediate stiffeners may extend only half the depth of the girder unless they are required to be of full depth to stiffen the web.

Centering and Locking Devices.

303. Bascule and vertical lift bridges shall be provided with self-centering and seating devices at the free end. There shall be a locking device for each truss to force down and hold the free end.

Air Buffers.

304. Power operated bascule and vertical lift bridges shall be provided with air buffers; for single track bridges, one at the free end of bascules, and one at each end of vertical lifts. For multiple track bridges, twice the number shall be used. The inside diameter of the cylinder shall be not less than 12 inches, and the travel of the piston not less than 24 inches. There shall be three cast iron packing rings for each piston.

End Lift.

305. The end lifting apparatus of swing bridges shall be arranged to center the bridge accurately when closed. The end lifting apparatus and center wedges shall be designed so that the action of the moving load cannot cause displacement of the end supports and wedges in case of failure or disconnection of the mechanism which actuates the end lift.

Counterweights.

306. Counterweights shall be of concrete supported by a steel frame. They shall be made adjustable so that the variations in weight of the moving span may easily be taken care of. Usually this shall be done by adding or taking off properly located cast iron or concrete blocks. Space for 2½ per cent. under and 5 per cent. above the calculated weight shall be provided. Movable blocks to the extent of 2½ per cent. shall be provided. Unless special aggregate is used, the concrete shall be assumed to weigh 145 lbs. a cubic foot.

In vertical lift bridges the counterweights shall clear the track rails by at least 3 feet when the span is fully opened. The counterweight ropes shall be assumed to stretch one per cent. of their figured length.

307. In vertical lift bridges, the counterweights shall be divided into parts so that each part will be hung by not more than sixteen ropes. The ropes of each group shall be attached to the part by an equalizer.

Pockets in Counterweights.

308. Pockets in counterweights shall be provided with drain holes not less than six inches in diameter. The pockets shall be covered. The cover, its fastenings and frame shall be of metal.

Concrete.

309. Concrete shall be composed of 1 part Portland cement, 2½ parts sand, and 5 parts stone. Otherwise the concrete shall conform to the specifications of the Company. In counterweights, steel punchings or scrap metal may be used to increase the weight. For ascertaining the weight of the concrete, test blocks having a volume of three cubic feet shall be cast from time to time as the concreting proceeds. Concrete counterweights exposed to the weather shall be covered with a waterproof coating.

Diameter of Sheaves.

310. For counterweight ropes, the diameter of the sheave shall be at least 80 times the diameter of the rope; 90 times is preferable. For operating ropes, the diameter of the drum shall be at least 45 times the diameter of the rope; 50 times is preferable.

Disc Bearings.

311. Center-bearing bridges shall revolve on disc bearings. Disc bearings shall consist of three discs, one of phosphor-bronze between two of hardened steel.

Center Pivots.

312. Center pivots shall be designed so that the discs may be taken out and replaced when the bridge is closed without interfering with the operation of trains over the bridge. The hardened steel discs shall be provided with effective means to prevent sliding except on the surfaces of the bronze disc.

Balance Wheels.

313. Wheels, no fewer than eight, running on a circular track, shall be provided to limit the tilting of center bearing bridges and to carry the wind pressure to the track while the bridge is swinging. The wheels shall be adjustable in height.

Wheels shall be fastened to their axles by keys.

Rack and Track.

314. The height of the track of swing bridges shall be not less than two-thirds of the width of the roller tread. The track segments shall be alike, and each about six feet long. They shall be anchored to the masonry with bolts not less than 1½ inches in diameter and 15 inches long, set in Portland cement grout 12 inches in the masonry. The space

between the bolt and the metal of the track shall be filled with molten type metal. Washers shall be provided under the nuts. The track shall be connected to the center by no fewer than eight radial struts.

The rack shall be fastened to the track so that the parts may be easily removed, except that in center bearing bridges the rack and track may be cast in one piece. The rack segments shall be alike and about 6 feet long.

Segmental Girders and Track Girders.

315. The flanges of the segmental girders and the track girders of rolling bridges shall be symmetrical about the central planes of the webs. The central planes of the webs of the segmental girders shall coincide with the corresponding central planes of the webs of the track girders. That part of the outstanding leg of a flange angle which is beyond the outside face of the vertical leg shall not be considered as bearing area. The width of contact between the segmental girder and the back of the tread plates shall be equal to the corresponding width of contact in the track girder. In bascule spans having a rolling load of 1,500,000 lbs. or more, the treads shall be solid steel castings, not less than 12 inches deep, securely fastened to the girders.

Rollers with a full circumference shall be rolled, forged, or cast into one solid piece.

Machinery Design.

316. The machinery shall be simple in design, and easily erected, inspected, adjusted, and taken apart. The fastenings shall be adequate to hold the parts in place under all conditions of service. Preferably the machinery shall be mounted on a solid cast frame or base.

Location of Machinery.

317. The location of the machinery shall be such as to allow convenient access and room for ample proportions of supporting parts. In bascule bridges, the machinery preferably shall be on the stationary part.

Bearings.

318. Bearings shall be placed close to the points of loading. The bearings for mating beveled gears shall be made in one solid piece. The length of a bearing shall not be less than the diameter of the journal. (613)

319. Journal bearings shall be of the divided type. The cap shall be recessed into the base. The cap shall be fastened to the base by turned bolts recessed into the base; cap screws for this fastening will not be accepted. Nuts shall be hexagonal. Check nuts shall be provided. The holes in the supports shall be ¼ inch smaller than the bolt, for subsequent reaming. The nuts of bolts shall bear on finished bosses cast on the bearing. The bearings shall be designed to facilitate cleaning, outlets being provided for flushing.

Linings.

320. Bearings for main pinion shafts and for shafts carrying heavy loads shall have phosphor-bronze linings; for other cast steel bearings,

the lining may be of bronze or babbitt metal. The lining shall be provided with an effective device to prevent rotating. The force tending to cause rotation shall be taken as one-eighth of the load on the trunnion or bearing and as acting at the outer circumference of the lining. There shall be ⅛ inch clearance between the lining of the cap and the lining of the base. The inside longitudinal corners of the lining shall be rounded except for a distance of ⅜ inch from each end. Cast iron bearings need not be lined.

Main Pinion Shaft Bearings.

321. In swing bridges, the brackets supporting the shaft bearings of the pinion which gears into the rack shall be in one piece so that the bearings may be bored in line and to prevent their getting out of adjustment. The bearings shall be provided with caps, so that the pinion shaft may be taken out without removing the bracket. An effective device shall be provided to prevent the pinion from moving lengthwise on the shaft. The strength and fastenings of the bracket shall be such as to take care of the one-sided action of the pinion.

Lubrication.

322. Provision shall be made for the effective lubrication of journals, pivots, and other sliding surfaces. Lubricating devices shall be easily accessible. Screw compression tell-tale grease cups shall be provided for journal bearings. If not accessible, the cups shall be connected with pipes. Grease ducts shall be located so that the lubricant will tend to flow by gravity toward the bearing surface. Grooves shall be provided wherever necessary for the proper distribution of the lubricant.

The grooves for large trunnion bearings shall be cut in the trunnion. They shall be straight, parallel with the axis of the trunnion, and no fewer than three. They shall be located so that the entire bearing surface of the lining will be swept by the lubricant in one movement of opening or closing the bridge. The bottom of the groove shall be rounded and the corners rounded to a ¼ inch radius. The size shall be such that a $\frac{5}{16}$ inch wire will lie wholly within the groove. The grooves shall be accessible for cleaning with a wire.

Covers.

323. Dust covers shall be provided wherever necessary to protect the sliding and rotating surfaces and prevent dust from mixing with the lubricant.

If gears are located where falling objects may foul them, they shall be protected by easily removable metal covers.

Counterweight sheave rims shall be covered to protect them from the weather.

Shafts.

324. For shafts supporting their own weight only, the unsupported length of the shaft shall not exceed $L = 80 \sqrt[3]{d^2}$ in which: L = length of shaft between bearings in inches; d = diameter of shaft in inches.

Line shafts connecting the machinery at the center of the bridge with that at the ends shall be designed to run at fairly high speed, the speed reduction being made in the machinery at the end.

Shafts transmitting power for the operation of the bridge, and shafts four feet or more in length forming part of the operating machinery of rail locks and bridge locks, shall not be less than 2½ inches in diameter.

Journals on cold rolled shafting shall not be turned down.

Collars.

325. Collars shall be used wherever necessary to prevent the shaft from moving lengthwise. There shall be at least two set screws, at an angle of 120 degrees, in each collar. If a shaft, trunnion, or axle receives a longitudinal force, there shall be a thrust bearing to prevent longitudinal movement.

Longitudinal Thrust.

326. Wheels and similar parts shall be securely fastened, to prevent longitudinal movement, by set screws through the hub or by clamps around the shaft. The hubs of beveled gear wheels shall bear against the shaft bearing. In any case, provision shall be made for any force tending to move the wheel along the shaft or axle.

Foot Step Bearings.

327. The lower ends of vertical shafts running in foot step bearings shall be of tool steel and shall run on bronze discs.

Shaft Couplings.

328. Shafting liable to be thrown out of line by reason of the deflection of the supporting structure shall be made in non-continuous lengths connected by claw couplings. These couplings shall be fitted together accurately but with allowance for a slight angular motion without bending the shaft. Each length of shafting of this kind shall rest in not more than two bearings. The couplings shall be close to the bearings.

Couplings in shafting other than the abovementioned shall be of the flanged or the split muff type. The bolt heads and nuts shall be seated in recesses or be protected by flanges. The couplings shall be cylindrical. They shall be keyed to the shaft.

Gear Teeth.

329. Gear teeth shall be of the involute type. The angle of obliquity shall be 20 degrees. The radial height of the tooth above the pitch line shall not exceed 0.32 of the circular pitch.

The width of face of a spur tooth shall not be less than 1½ times the circular pitch. For pitch circle speeds not exceeding 600 feet per minute, the width shall not be more than three times the circular pitch. The width of face of a bevel tooth shall not exceed one-third of the slant height of the pitch cone, or three times the pitch at the middle section.

The circular pitch of gear wheels (other than motor pinions) transmitting power for moving the span shall not be less than one and one-fourth inches. For the pinion engaging the operating rack, the pitch shall not be less than two inches.

Strength of Gear Teeth.

330. The strength of cut gear teeth shall conform to the following formula, one tooth taking the whole pressure.

$$W = 2stf\ \left(0.154 - \frac{0.912}{n}\right)\left(\frac{600}{600 + V}\right)$$

W = the pressure on the tooth in pounds.
s = permissible unit stress = 16000 lbs. for steel,
= 9000 lbs. for bronze.
f = width of face of tooth in inches.
t = thickness of tooth measured on pitch circle.
V = velocity of pitch circle in feet a minute.
n = the number of teeth in the gear.

The strength of machine molded teeth shall conform to the foregoing formula taking $s = 14000$.

The foregoing formula shall apply to worm wheels assuming W equally divided between two teeth.

In estimating the strength of teeth in bevel wheels, the middle section shall be taken.

The strength of shrouded teeth shall be computed as for uncut teeth.

Teeth to Be Cut.

331. The teeth of wheels transmitting power for the operation of the bridge, bevel wheels, and wheels in the gearing of any motor, shall be machine cut. (517)

Equalizing Devices.

332. In truss swing bridges, there shall be at least two pinions on the rack. The shafts of these pinions shall be connected by a device which will equalize the turning forces at the pinions.

There shall be devices on bascule and vertical lift bridges to equalize the action between the pinions and the operating racks.

Worm and Screw Gearing.

333. In worm and wheel gearing and screw gearing for transmitting power, the angle of thread shall be not less than 20 degrees. The worm shall run in oil. There shall be a bronze or brass collar at the ends of the screw in screw gearing and on the worm wheel axle in worm gearing to take the end thrust. The wheel in worm gearing and the nut in screw gearing shall be of bronze. Screws shall have square threads. Worm wheels shall have no fewer than 30 teeth. Worm and wheel gearing shall be enclosed in a cast iron casing. The worm shall be below the wheel.

Except for end lifts of swing bridges, worm and screw gearing preferably shall not be used for transmitting power. Cams and similar mechanisms transmitting power by line or point contact shall not be used.

Springs.

334. Springs preferably shall not be used to actuate any moving part. For electrical parts, preference will be given to those having the fewest springs.

Keys and Keyways.

335. Keys for keying machinery parts to shafts shall be hooked and tapered if practicable. If tapered keys are not practicable, they may be parallel faced. The keys shall be sunk in grooves in both hub and shaft.

The taper of the key shall be ⅛ inch per foot. The width shall be one-fourth of the diameter of the shaft. The height at the middle of the tapered length shall be three-fourths of the width. The length of the hook, measured parallel with the shaft, shall be equal to the width of the key. The foregoing dimensions are approximate; the shape of the key and the depth of the groove shall be such that the allowed unit stresses in shear and bearing will not be exceeded.

The length of the tapered part of the key shall be not less than that of the hub plus one-fourth of the diameter of the shaft.

Saddle Keys.

336. If a loose fit of the hub is specified, there shall be a saddle key at an angle of 120 degrees from the sunk key. The width of the saddle key shall be one-fourth of the diameter of the shaft. Its height, measured on the center line of the cross section, shall be one-twelfth of the diameter of the shaft. The length of the saddle key shall be one and one-fourth times the length of the hub. The curved surface shall fit the shaft. The key shall be contained in a groove of the hub only, of such depth that there will be a tight fit between hub and shaft when the sunk key is driven home.

Capacity of Keys.

337. The foregoing requirements for keys and keyways are for machinery parts whose use is intended to develop the full torsional strength of the shaft. For minor parts, the keys and keyways shall be proportioned for that size of shaft whose torsional strength would be developed by such parts.

For trunnions and similar parts which are designed chiefly for bending and bearing, the keys and keyways shall be proportioned simply to hold the trunnion from rotating. The force tending to cause rotation shall be taken as one-fifth of the load on the trunnion, and as acting at the circumference of the trunnion.

Fastening Keys.

338. Keys shall be held by safety set screws or other effective means. In vertical shafts, bands clamped about the shaft, or other devices, shall be placed below the key.

If practicable, the keys and grooves shall be made so that the keys may be backed out.

If two keys are used, they shall be placed at an angle of 120 degrees.

Hubs.

339. If practicable, the length of the hub shall be not less than twice the diameter of the shaft, and its thickness not less than two-fifths of the diameter of the shaft.

The fit of the hub on the shaft shall be a light driving fit, unless otherwise specified.

The groove in the hub shall be on the center line of an arm.

Bolts and Nuts.

340. Bolt heads and nuts shall bear on seats at right angles with the bolts. On castings, except where recessed, such seats shall be bosses. Bolt heads which are recessed in castings shall be square.

Nuts which are subject to vibration and frequent changes of load shall be secured by effective locks. If double nuts are used, each nut shall be of the standard thickness.

Set Screws.

341. Set screws shall not be used for transmitting torsion to shafts or axles. They may be used for holding keys or light parts in place.

Tap and Stud Bolts.

342. Tap bolts and stud bolts shall not be used except by special permission of the Engineer.

Operating Ropes.

343. For operating ropes, there shall be at least two full circumferential turns of the rope on the drum when the span is in the fully open or fully closed position. If practicable, the number of turns shall be sufficient to develop the ultimate strength of the rope by friction, the coefficient of friction being taken as 0.20. The rope shall be attached to the drum so as to avoid sharp bends in the wires. There shall be a turnbuckle or other device for taking up slack in the rope.

Counterweight Ropes.

344. The deviation of counterweight ropes from the vertical shall be as small as practicable. The deviation from the plane through the center of the groove shall not exceed 1 in 40.

Rope connections shall be made so that any rope may be renewed without disturbing the remaining ropes.

Safety Guards.

345. Safety guards for the protection of persons shall be installed. All local safety regulations shall be observed.

Built Sheaves.

346. In built sheaves, there shall be enough rivets connecting the flanges of the cast rim with the web to carry into the web all of the load coming on the rim. The rim shall be strengthened by transverse ribs, or shall be thick enough to carry the load.

Drainage Holes.

347. At places where water is likely to collect, there shall be drainage holes not less than one inch in diameter.

Equalizing Levers.

348. The net section back of the pin hole in equalizing levers shall be equal to the net section which would be required in tension to carry the load on the pin.

4. Wire Ropes and Attachments.

Manufacturer.

401. Wire rope shall be made by a manufacturer whose facilities and reputation are approved by the Engineer.

Laying.

402. Ropes shall be laid up in the best manner. They shall be soaked thoroughly in an approved lubricant during the process of manufacture.

Splices.

403. Ropes shall not be spliced.

Wire Ropes.

404. The diameter of counterweight ropes shall not be less than one inch, nor more than two and one-half inches; for operating ropes not less than three-quarters of an inch.

The ropes shall be made of plow steel and consist of 6 strands of 19 wires each laid around a hemp center.

Sockets.

405. Sockets shall be forged without welds from solid steel. The dimensions of sockets shall be such that no part under tension will be stressed higher than 65,000 lbs. per square inch when the rope is stressed to its specified ultimate strength. The sockets shall be attached to the rope by a method which is reliable and which will not permit the rope to slip in its attachment to the socket.

Wire—Physical Properties.

406. The wire from which counterweight ropes are made shall be

tested in the presence of an Inspector designated by the Engineer. It shall show the following physical properties:

(a) A tensile strength of not less than 225,000 lbs. per square inch.

(b) A total elongation, measured on a piece 12 inches long, of not less than 2.4 per cent.

(c) The number of times a piece 6 inches long can be twisted around its longitudinal axis without rupture shall be not less than 1.4 divided by the diameter in inches.

(d) The number of times the wire can be bent 90 degrees alternately in opposite directions over a jaw the radius of which is equal to twice the diameter of the wire without fracture shall not be less than six. This test shall be made in a mechanical bender so constructed that the wire actually conforms to the radius of the jaws and is subjected to little tensile stress.

Ultimate Strength.

407. In order to show the strength of the rope and fastenings, a number of test pieces not more than twelve feet long, with sockets, selected at random from those which are to be used in filling the order, attached to each end shall be stressed to destruction in a suitable testing machine. The number of test pieces shall not be more than ten per cent. of the total number of finished lengths of rope to be made, nor less than two from each original length. Under this test, the rope shall develop the ultimate strength given in the table below.

ULTIMATE STRENGTH IN POUNDS.

6 x 19 Plow Steel Rope.

Diameter of Rope in inches.	*Area of Section* $.4D^2$	*Ultimate Strength* *Lbs. per sq. in.*	*Total.*
¼	.025	208,000	5,000
⅜	.056	204,500	11,000
½	.100	201,200	20,000
⅝	.156	198,100	31,000
¾	.225	195,200	44,000
⅞	.306	192,500	59,000
1	.400	190,000	76,000
1⅛	.506	187,700	95,000
1¼	.625	185,600	116,000
1⅜	.756	183,700	139,000
1½	.900	182,000	164,000
1⅝	1.056	180,500	191,000
1¾	1.225	179,200	220,000
1⅞	1.406	178,100	251,000
2	1.600	177,200	284,000
2¼	2.025	176,000	356,000
2½	2.500	175,600	439,000

Rejection.

408. If the physical qualities of the rope or of its individual wires fall below those specified, the entire length from which the test pieces were taken shall be replaced by the manufacturer with a new length, the physical qualities of which come up to those specified.

Testing Sockets.

409. If in testing, slipping in the sockets should occur, the method of fastening the sockets shall be changed until slipping is avoided. The sockets shall be stronger than the rope to which they are attached. If a socket should break during the test, two others shall be selected and attached to another piece of rope and the test repeated. This process shall be continued until the Inspector is satisfied of the reliability of the sockets. If the Inspector is so satisfied, the lot shall be accepted. If, however, 10 per cent. or more of the sockets tested break at a load less than the specified minimum ultimate strength of the rope, the lot shall be rejected.

Test of Finished Ropes.

410. The Engineer reserves the right to test one-fourth of the finished ropes, including fastenings and sockets up to twice the working load. If any defects are found, the test may be repeated at the option of the Engineer up to the full number of ropes. Defective parts shall be rejected and replaced.

Facilities for Testing.

411. The manufacturer shall provide proper facilities for making the tests, and shall make, at his own expense, the tests required. Tests shall be made in the presence of an Inspector representing the Engineer.

Length.

412. The length of each rope shall be measured while the rope is supported throughout its length in a straight line and under a tension of 4 per cent. of its ultimate strength. A variation from the required length at the rate of not more than one-quarter of an inch in 100 ft. of length will be allowed.

Coils.

413. Ropes shall be shipped in coils. The diameter of the coil shall be at least thirty times that of the rope. Ropes shall be uncoiled for use by revolving the coil; not by pulling the rope away from the stationary coil.

Equalizing Levers.

414. The equalizing levers and their pins over 4 inches in diameter shall be of forged steel. Pins 4 inches or less in diameter shall be made of either rolled steel or forged steel.

5. WORKMANSHIP.

Planing Girders.

501. In built track girders and segmental girders of rolling bascule bridges, and in the lower flanges of the drums of rim-bearing swing bridges, the edges of the webs, side plates, and angles shall be planed so that a full bearing on the track plate will be secured.

Rack and Track.

502. Track segments shall be planed on the top and bottom and at the joints. Surfaces on which conical rollers bear shall be planed to the true bevel. The center line shall be scribed plainly on the surface.

The toothed segments forming the rack shall be fitted accurately. Particular care shall be taken to have the pitch of the teeth at the joints accurate. Both the periphery and the ends of rack teeth which mesh with a shrouded pinion shall be planed. The pitch line shall be scribed on the ends of the teeth.

In swing bridges, the rack segments shall be fitted to those of the track so that the center line of the track will be concentric with the pitch line of the rack.

The backs of racks which bear on metal surfaces and the surfaces in contact with them shall be planed.

Tread Plates.

503. In rolling bridges, the top and bottom surfaces of the tread plates and the surfaces in contact shall be planed.

Rollers.

504. Rollers shall be turned at the circumference and at the faces of the rim, the corners shall be chamfered, and the center line of the roller shall be marked on the circumference. The hubs shall be bored and faced accurately at each end.

Pivots.

505. Pivot stands and center castings of swing bridges shall be finished and fitted accurately. The base shall be faced truly at right angles with the axis and shall be turned on the circumference concentric with the axis.

Discs.

506. Steel discs shall be of tool steel. They shall be fitted accurately, finished to gage, and oil tempered. After hardening, they shall be ground accurately to the final finish. The sliding surfaces of steel and phosphor-bronze discs shall be polished. Disc centers shall be assembled, fitted accurately and match-marked.

Assembling Centers.

507. The complete centers of swing bridges, including rack, track segments, and rollers, shall be assembled in the shop, alined, fitted, drilled, and the parts match-marked.

Fillets.

508. Shafts, trunnions, and axles shall be made with fillets where abrupt changes in section occur.

Journals.

509. Journals, trunnions, and linings shall be polished after being turned. Journals of shafts which are not cold rolled shall be turned with a filleted collar at each end. (324)

In journals more than eight inches in diameter, there shall be a 1½ inch hole bored longitudinally through the center.

Couplings.

510. The faces of flange and split muff couplings shall be planed to fit.

Hubs.

511. The hubs of wheels, pulleys, couplings, etc., shall be bored to a close fit on the shaft or axle. If the hub performs the function of a collar, the end next to the bearing shall be faced. Hubs shall be bored truly at the center of the wheel.

Linings.

512. Bearings shall be bored for the journal and finished smoothly after the lining has been put in. The bearing shall be bored 1/50 inch larger than the diameter of the journal. Bearings for rack pinion shafts shall be bolted to the bracket supporting them and bored while so fastened, so as to insure a perfect alinement. The edges of oil grooves and the edges of linings shall be rounded.

Bronze linings shall be turned on the outside to fit the bored hole in the bearing.

Babbitt metal shall be poured in the bearings around a mandrel ¼ inch smaller in diameter than the journal. The mandrel shall be placed so that the thickness of the lining after boring will be uniform.

Bearings.

513. The rubbing and bearing surfaces and the joints between cap and base of bearings shall be finished. The holes in cap and base shall be drilled. The holes in the bearings for fastening them to their supports shall be drilled $\frac{1}{16}$ inch larger than the bolts. The holes in the supports shall be reamed to fit after the bearings have been adjusted.

Gear Wheels.

514. The periphery of gear wheels shall be turned. The pitch circle shall be scribed on both ends of the teeth.

Bevel Gears.

515 The teeth of bevel gears shall be cut by a planer having a rectilinear motion in lines through the apex of the cone. Rotating milling cutters shall not be used for making bevel gears.

Shrouded Pinions.

516. At the junction of the shrouding and teeth, cleaning, chipping, or other means shall be used to insure the meshing of the pinion teeth and rack teeth.

Machine Molding.

517. Uncut teeth shall be machine molded. (331)

Worms and Worm Wheels.

518. Threads on worms shall be cut, and the teeth of worm wheels shall fit the worm accurately with line contact.

Keys and Keyways.

519. A special effort to secure good workmanship on keys and keyways shall be made. Keys shall be planed and keyways machine cut. The finish of the keyways and key shall be such as to give the key a full bearing on bottom and sides with a driving fit on the sides. If practicable, the groove in the shaft shall be made long enough to allow the key to be inserted without moving the hub sidewise and long enough to extend beyond the point of the key, after the key is firmly seated, a distance not less than three-eighths of the diameter of the shaft. The clear distance between hub and hook of key shall not be less than one-fourth of the diameter of the shaft. Tapered keys shall bear on top, bottom and sides; parallel faced keys on sides only.

Castings.

520. Castings shall be cleaned and fins and other irregularities removed. Bosses shall be finished to the correct plane. (340)

Castings which are to be attached to unfinished surfaces shall be provided with chipping strips. The outer unfinished edges of ribs, bases, etc., shall be rounded off and inside corners filleted.

Bolt Holes and Turned Bolts.

521. Holes for unfinished bolts shall be drilled or reamed not more than $\frac{1}{16}$ inch larger in diameter than the bolt. The diameter of the shank of turned bolts shall be at least $\frac{1}{16}$ inch larger than the diameter of the threaded portion. The bolt shall make a driving fit in the bolt hole.

Assembling Machinery.

522. Machinery parts shall, if practicable, be assembled on the supporting members in the shop. They shall be alined and fitted, and holes in the supports shall be drilled with the members in correct relative position. The members shall be match-marked both to the supports and to each other, and re-erected in the same relative positions. If assembling is not practicable, the holes in the supports shall be left blank and drilled in the field after the machinery parts are assembled and alined.

Equalizing Levers.

523. Equalizing levers in wire rope connections shall be neatly finished and shall conform to the dimensions shown on the drawings.

Grooves in Sheaves.

524. The grooves in sheaves shall be turned. Built sheaves shall be assembled and permanently riveted before being turned.

Grooves in Trunnions.

525. The grooves in the surfaces of trunnions and similar large bearings shall be machine cut. Small inequalities may be removed by chipping and filing. The grooves shall be smooth, especially the rounded corners.

Holes for Sheaves for Vertical Lift Bridges.

526. The holes in the girders and columns for the bolts connecting the main sheave bearings of vertical lift bridges to their supporting girders shall be drilled from the solid through cast iron or steel templates on which the bearings were set and accurately lined when the holes in the bearings were bored. The bolt holes and the bolts shall be turned to the same diameter and the bolts driven to place without injury to them, the bearings, the girders, or the columns.

Air Buffers.

527. The workmanship on air buffers shall be so accurate that the weight of the cylinder and its attachments will be sustained by the confined air for six minutes, with a piston travel not more than that which occurs during the closure of the bridge. The valves must be closed and the buffers balanced so that the whole weight is carried by the piston rod.

6. Loads, Unit Stresses, and Proportioning of Parts.

Stresses in Swing Bridges.

601. The stresses in trusses or girders of swing bridges continuous over three or four supports shall be calculated for the bridge in the following conditions:

1. Bridge open, or closed with ends just touching.
2. Bridge closed with ends lifted.

The computation of stresses shall be divided into the following cases:

Case I. Condition 1, dead load.

Case II. Condition 2, dead load, ends lifted to give positive reaction equal to one and a half times the maximum live load negative reaction plus impact.

Case III. Condition 1, live load on one arm as a simple span.

Case IV. Condition 2, live load on one arm, bridge as a continuous girder.

Case V. Condition 2, live load on both arms, bridge as continuous girder.

The following combinations of these cases shall be used in determining the maximum stresses:

Case I alone.
Case I with case III.
Case I with case V.
Case II with case IV.
Case II with case V.

The stress sheet shall show the stresses in the different members for each of the foregoing cases, together with the combinations which give the greatest positive and negative stresses in each member.

In computing the live load stresses, the live load shall be considered as applied, either continuously or in detached parts, in such a manner as to produce the maximum stresses.

Impact.

602. Stresses in structural parts, which vary with the movement of the span, shall be increased 20 per cent. as an allowance for impact. This impact allowance shall not be taken in combination with the train-load stresses.

Stresses in structural parts caused by the machinery or by forces applied for moving the span shall be increased 100 per cent. as an allowance for impact.

The end floor beams of the moving span and the adjacent floor beams of the fixed spans shall be proportioned for a concentrated load of 85,000 lbs. on each track in addition to the specified train load and impact.

End Ties.

603. The first two ties of the moving span and of the fixed spans shall be supported throughout their length so as to be relieved from bending. They shall be not less than 10 in. thick and in no case of less thickness than the remainder of the ties. The supports for these ties, if other than end floor beams, shall be proportioned for two and one-half times the 85,000-lb. axle load.

Reversal of Stress.

604. Structural members subject to reversal of stress during the motion of the span shall be proportioned for the stress giving the larger section (602). The riveted connections shall be proportioned for the static stress plus impact plus 25 per cent.

End Lift Reactions.

605. The end lifting machinery of swing bridges shall be proportioned to exert an uplift equal to the maximum negative end reaction of the live load and impact plus 25 per cent. of both. The end bearings shall be proportioned for the maximum positive end reaction including impact.

The center wedges and supports shall be proportioned for the reaction of the live load and impact.

Rollers.

606. The rollers of rim bearing or combined rim bearing and center bearing swing bridges shall be proportioned for the dead load stresses when the bridge is swinging, and for the dead and live load and impact stresses when the bridge is closed.

In computing the load on the rollers, the drum shall be considered as distributing the load uniformly over a distance equal to twice the depth of the drum, back to back of flange angles. This distance shall be taken as symmetrical about the vertical through the point of application of the concentrated load.

Wind Load and Ice Load.

607. In proportioning the members and determining the stability of the moving span and the towers of bascule bridges and vertical lift bridges when in the open position, the wind pressure shall be assumed as 15 lbs. a square foot, applied to the exposed surface of the trusses and floor as seen in elevation.

In determining the stability of swing bridges when open, the wind pressure shall be assumed as 10 lbs. a square foot acting on the horizontal projection of one arm.

For open deck bridges the area of the floor exposed to wind and ice shall be taken as 85 per cent. of the area of a quadrilateral, whose width is the distance center to center of trusses and whose length is that of the floor of the span. For bridges with solid floors, or with foot walks, the actual exposed floor surface shall be taken.

In proportioning the members and determining the stability of the bridge when closed, the assumed wind loads shall be in accordance with the General Specifications for Steel Railway Bridges of the American Railway Engineering Association.

607a. For proportioning the machinery and determining the power required for operation, the various loads shall be assumed as applied in the following manner:

For bascule and unequal arm swing bridges, the machinery shall be proportioned to hold the span in any position with a wind load of 15 lbs. a square foot on any vertical projection of the open bridge. In proportioning the machinery for this condition the stresses specified herein may be increased one-fourth.

The machinery shall be proportioned and power provided to move the span under the following conditions:

(A) In the normal time for opening; (103).

1. Bascule bridges and vertical lift bridges against frictional resistances, and a wind load of 2½ lbs. a square foot of the floor area, acting normally to the floor.

2. Swing bridges against frictional resistances, and a wind load of 5 lbs. a square foot of the vertical projection of one arm.

(B) In one and one-half times the normal time for opening;

Bascule bridges and vertical lift bridges with an ice load of 2½ lbs. a square foot of floor area in addition to the loads specified in (A).

(C) In twice the normal time for opening;

Bascule bridges and unequal arm swing bridges against frictional resistances, a wind load of 10 lbs. a square foot of any vertical projection and an ice load of 2½ lbs. a square foot on the floor area.

Machinery Resistances.

608. In calculating the resistances to be overcome by the machinery, the resisting forces shall be reduced to a single force acting between the pinion and the operating rack, or in the operating cable. In determining this force, the following coefficients shall be used:

	For Starting	*For Motion*
For trunnion friction:		
a. One or more complete rotations	0.135	0.09
b. Less than one complete rotation	0.18	0.12
For friction on center discs	0.15	0.10
For rolling friction of bridges having rollers with flanges, or built-up segmental girders	0.009	0.006
For collar friction at the ends of conical rollers	0.15	0.10
For stiffness in wire ropes per 180 deg. of bending, (d = dia. of rope in inches, D = dia. of sheave in inches).	$\frac{2d^2}{3D}$	$\frac{2d^2}{3D}$
For rolling friction of solid cast rollers without flanges:		
a. In contact with one surface only	$\frac{3}{200r}$	$\frac{3}{200r}$
b. In contact with two surfaces	$\frac{3}{100r}$	$\frac{3}{100r}$

(r = the radius of the roller in inches.)

In designing the machinery for holding the span against the 15 lbs. wind pressure specified, and for computing braking effect, 0.4 of the above mentioned coefficients for motion shall be used. Rope stiffness, solid roller friction, and machinery friction shall be disregarded.

For sliding friction between plane surfaces intermittently lubricated (such as guides on tower posts), the coefficient of friction shall be taken as 0.08.

Machinery Losses.

609. In computing the machinery losses between the operating rack, or the operating rope, or similar points, and the prime mover, the following coefficients shall be used:

For journal friction	0.05
For the efficiency of any pair of gears, journal friction included:	
Spur gears	0.93
Bevel gears	0.85
Efficiency of worm gearing, angle of thread 20 deg. or more, collar friction included	0.60

Brakes.

610. The machinery, including the brake mechanism, shall be capable of resisting the stresses caused by stopping the bridge in five seconds. The braking capacity shall be sufficient to stop the bridge in ten seconds. The coefficient of friction for braking shall be taken at 0.25. If practicable, the pressure per square inch on the rubbing surface of the brake shall not exceed 25 lbs.

If brakes act through the machinery, the unit stresses produced in the machinery by braking shall not exceed 1½ times those allowable for the normal torque of the prime mover. However, for the braking mechanism and for parts which receive stress only through braking, the unit stresses shall not be increased.

Unit Stresses.

611. Structural parts shall be proportioned by the General Specifications for Steel Railway Bridges of the American Railway Engineering Association.

The following unit stresses in pounds per square inch shall be used for machinery and similar parts in which main stresses are not increased by impact:

Material	*Tension*	*Compression*	*Fixed Bearing*	*Shear*
Rolled or Forged Steel......	9000	$9000-40\frac{l}{r}$	13000	6500
Cast Steel	7000	$8000-35\frac{l}{r}$	10000	5000
Phosphor Bronze	6000	6000		4500
Cast Iron	1500	8000*	8000	2000
Keys			9000	5000

*For struts whose $\frac{l}{r}$ is 20 or less.

For stresses which are reversed at the rate of ten or more times per minute, two-thirds of the above mentioned unit stresses shall be used.

For nickel steel, the above mentioned unit stresses may be increased one-half.

Bearing Pressures.

612. The following maximum bearing pressures in pounds per square inch for rotating and sliding surfaces shall be used:

a. For intermittent motion with speed not exceeding 100 ft. per minute:

Pivots of swing bridges, hardened tool steel on phosphor bronze discs..........................	3000
Trunnion bearings, structural steel on phosphor bronze	1500
Wedges, cast steel on cast steel or structural steel.	500
Screws which transmit motion (on projected area of thread)	200

b. For speeds exceeding 100 ft. per minute:

Hardened steel on hardened steel	2000
Hardened steel on bronze	1500
Structural steel on bronze	600
Structural steel on babbitt metal or brass	400
Structural steel on cast iron	400
Cross-head slides (speed not exceeding 600 ft. per minute)	50

Journal and Pivot Bearings.

613. The pressure on pivots or footstep bearings for vertical shafts, and on journals shall not exceed:

On pivots, $p=\frac{60000}{nd}$, but not more than 900.

On journals, $p=\frac{250000}{nd}$, but not more than 600.

On collars, $p=\frac{50000}{nd}$, but not more than 200.

p = pressure in pounds per square inch.
n = number of revolutions per minute.
d = diameter of pivot or journal or mean diameter of collar in inches.

For crank pins and similar joints with alternating application and release of pressure, the bearing values given by the foregoing formulas may be doubled (318).

Pressure on Rollers.

614. The permissible pressure in pounds per linear inch of rollers shall be:

For rollers in motion:

Cast iron	200d
Cast steel	400d
Structural steel	300d
Tool steel	800d
Hardened tool steel	1000d

For rollers at rest:

Rolled or cast steel	600d

d = diameter of roller in inches.

The foregoing values are for rollers and bearing surfaces of like materials. If the rollers and bearing surfaces are of unlike materials, the lower value shall be used.

Wire Ropes.

615. The total unit tension in counterweight ropes shall not exceed one-fifth of the specified unit ultimate strength of the rope, nor shall the unit tension from the direct load only exceed one-ninth of the difference between the specified unit ultimate strength and the unit bending stress.

For operating ropes, the corresponding limits shall be one-third and one-fifth.

616. If a wire rope is bent over a sheave, the bending stress and permissible load on the rope shall be calculated as follows:

Let P = the total pull or permissible load on the rope in pounds.
K = unit extreme fiber stress in largest individual wire due to bending.
E = modulus of elasticity = 28500000.
a = cross-sectional area of rope in square inches.
d = diameter of the largest wire in inches.
D = diameter of sheave, to center of rope, in inches.
S = greatest unit tension allowable.
L = angle of helical wire with axis of strand.
B = angle of helical strand with axis of rope.
c = diameter of rope.

$$\text{Then } K = \frac{Ed\cos^2 L\cos^2 B}{D} \quad \text{.....................................} (1)$$

$$P = a\left(S - \frac{Ed\cos^2 L\cos^2 B}{D}\right) = a\left(S - \frac{0.9\,Ed}{D}\right) \quad \text{........} (2)$$

For rope having 6 strands of 19 equal wires each,

$$P = a\left(S - \frac{1700000c}{D}\right) \quad \text{.....................................} (3)$$

$$\text{assuming } d = \frac{c}{15}.$$

For haulage rope, 6 strands of 7 wires each, $d = \frac{c}{9}$.

617. If a rope is in contact with a small sheave over a short arc (50 deg. or less), the actual radius of curvature of the rope may be greater than that of the sheave.

Let R = the actual radius of curvature of the rope.
Θ = the angle between the directions of the rope.
w = pull on individual wire (equal to P divided by the number of wires if all wires are of equal diameter).

$$\text{Then } R = \frac{d^2}{4.25\cos\frac{\Theta}{2}}\sqrt{\frac{E}{W}}$$

If R is greater than the radius of the sheave, 2R should be used in place of D in formulas (1), (2) and (3).

Shafts.

618. Circular shafts, trunnions and axles shall be proportioned by the following formulas:

$$f = \frac{32}{\pi d^3}\left(\frac{3}{8}M + \frac{5}{8}\sqrt{M^2 + T^2}\right).$$

$$S = \frac{16}{\pi d^3} \sqrt{M^2 + T^2}.$$

f = unit extreme fiber stress in tension or compression.
S = unit shear.
d = diameter of shaft at the section considered.
M = the simple bending moment computed for the distance center to center of bearings.
T = the simple twisting moment.

In the case of reversal at the rate of ten or more times per minute, increase M one-half. In this case, f shall not be reduced on account of reversal (611).

If a shaft, trunnion, or axle has one keyway cut at the section where the maximum stresses occur, f and S shall be considered to be increased by one-sixth; if two keyways are cut, by one-fourth.

Excess Loads.

619. The machinery parts shall be designed for the normal loads herein specified, using the unit stresses herein given. For the stresses caused by the motor when exerting twice the greatest normal torque, twice the normal unit stresses may be used (704).

End Lift Machinery.

620. In designing the machinery parts for the end lifts of swing bridges, the same methods specified for the machinery actuating the moving span shall be used.

Impact.

621. The allowance for impact in trunnions, wire ropes, wire rope attachments, and machinery parts is taken care of by the foregoing unit stresses.

7. Power Equipment.

a. General Requirements.

Kind of Power.

701. If the bridge is to be operated by mechanical power, the kind of power to be used will be stipulated by the Company. The motors shall be of ample capacity to move the bridge at the required speed. The type and the name of the manufacturer shall be given in the bid. The term motor, as used in these specifications, means the prime mover, whether steam, internal combustion, or electric.

Man Power.

702. If the bridge is to be operated by hand power, the number of men and the time required to operate it shall be calculated on the assumption that the force one man can exert continuously is 40 lbs. at a speed of 160 ft. per minute, developing about one-fifth h. p. For calculating the strength of the machinery parts, the force of one man shall be assumed as 125 lbs., and the force applied to the extreme end of the hand lever of any bridge shall be assumed as 150 lbs.

Machines.

703. Machines which are of the usual manufactured types, such as steam, gasoline, and electric motors, pumps, air compressors, etc., shall be tested for the specified requirements to the satisfaction of the Engineer, and shall be guaranteed by the manufacturer to fulfill these requirements for one year.

Break Test.

704. The rating of motors shall be the horsepower determined by the brake test. The motor shall be capable of exerting twice the greatest torque shown on the torque curves for the normal loads.

Electrical Control.

705. The kind of electrical control shall be manual or automatic as may be stipulated by the company.

Brakes.

706. Electrically operated vertical lift bridges shall be provided with a solenoid brake for each main motor (737), and in addition a motor operated service brake with 3 steps of retarding torque. If stipulated, the service brake may be operated by air. (738).

Electrically operated bascule bridges and swing bridges shall be provided with a solenoid brake for each main motor (737), and in addition with an emergency brake which shall be located as close to the operating rack, or drum, as practicable. (739), (743).

Brakes for bridges operated by power other than electricity shall be operated by air, by hand, or by foot.

Whistle.

707. A whistle or an electric horn shall be installed complete.

The horn shall be audible at a distance of 1500 ft. under the conditions surrounding the site and with the wind blowing in any direction.

The bell of the whistle shall be not less than 3 in. in diameter and 9 in. long. If the whistle is operated by air, the compressor shall be power driven, the motor and compressor being gear connected on one frame. The working parts shall be enclosed and self-lubricating. The compressor shall have a piston displacement of from 25 to 30 cu. ft. per minute when working against a tank pressure of 90 lbs. per square inch. The compressor shall be provided with an automatic governor and switch in order that the compressor may start and stop automatically at any predetermined tank pressures. The air receiving tank shall be 36 in. in diameter and 8 ft. long, or of equal capacity.

The tank shall be galvanized. It shall be good for a working pressure of 100 lbs. per square inch. It shall be provided with pressure gage, pop valve, and drain cock, and shall have standard flanges bushed for 1½-in. pipe. The contractor shall furnish and install pipe, pipe fittings, and valves; all to withstand a working pressure of 100 lbs. per square inch.

b. Steam.

Steam Engines.

708. Steam engines shall be of the double-cylinder, reversing type, and shall develop the required power at a piston speed not exceeding 400 ft. per minute with a steam pressure of 60 lbs. per square inch at the throttle. The engine shall be connected to the operating machinery by an approved friction clutch, arranged so that the moving machinery and the locking machinery may be operated independently or stopped without stopping the engine.

Steam Separator.

709. In the steam supply pipe close to the steam chest shall be placed a steam separator. This separator, under test with quality of steam as low as 66 per cent., shall show an average efficiency of 85 per cent. in 5 tests.

Boilers.

710. There shall be installed one or two boilers as stipulated. The boilers shall be upright tubular boilers with submerged tubes. They shall be designed for a steam pressure of 150 lbs. per square inch, and shall be adapted to the kind of fuel specified by the Engineer. Boilers shall be in accordance with the Code of the American Society of Mechanical Engineers adopted February, 1915, or subsequent revisions, and shall otherwise conform to civil regulations. They shall be encased in asbestos, covered with Russia iron.

Boiler stacks shall be made of ingot iron or other pure metal not less than $\frac{3}{16}$-in. thick. They shall be of ample diameter and height to furnish the required draft under the conditions at the site.

Horsepower of Boilers.

711. The horsepower of each boiler shall be twice that of the engine. The horsepower shall be computed by allowing 15 sq. ft. of heating surface per horsepower. There shall be at least $\frac{1}{3}$ sq. ft. of grate surface per horsepower.

Pipe Covering.

712. Steam pipes shall be covered with sectional covering approved by the Engineer. Water pipes shall be protected from freezing where necessary.

Engine Room Appliances.

713. In the engine room, there shall be a steel water tank of sufficient capacity, a duplex steam boiler feed pump, and an injector for each boiler, with necessary pipes and connections for feeding boilers separately or together. Steam water lifters with necessary strainers, flexible hose, and piping to lift the water from the river into the tank shall be provided where the river water is fit for boiler use. A coal hoist and a steel coal bin of sufficient capacity shall be provided. There shall be in the engine room indicators to show the positions of the moving span and of the lifting and locking apparatus.

c. Internal Combustion.

Gasoline Engines.

714. Gasoline and other internal combustion engines shall be low-speed engines of the most substantial kind. The piston speed shall not exceed 600 ft. per minute. The engine shall be equipped with a reversing gear, with approved friction clutches, to be operated by a hand wheel. The countershaft connecting the engine with the operating machinery shall be provided with disengaging couplings so arranged that the moving machinery and the interlocking machinery may be operated independently and in either direction without stopping the engine. Engines of 15 h. p. and more shall be equipped with a device for starting by compressed air. The engine room shall be provided with a water tank of sufficient capacity. The gasoline tank shall be located outside of the engine room, below the level of the cylinder. It shall be protected from the sun. There shall be in the engine room indicators to show the positions of the moving span and of the lifting and locking apparatus.

Cooling.

715. For bridges which are to be opened not more than four times per hour, the engine may be air cooled.

Ignition.

716. If the fuel is suitable (such as gasoline and kerosene), the ignition shall be of the jump-spark kind, for which the secondary coil is made up so that a low voltage primary current (not over 10 volts) will be sufficient. For other fuel, the best device available shall be used. Two extra ignitors and two extra crank pin brasses shall be furnished.

d. Electric.

Rules.

717. The electrical equipment shall conform to the Standardization Rules of the American Institute of Electrical Engineers as adopted June 21, 1907, or subsequent revisions.

The National Electric Code and the National Electric Safety Code shall apply to the electrical material, construction, and installation, except as may be provided otherwise herein.

717. The quality of the wires and insulation shall conform to the Specifications of the Railway Signal Association as revised and adopted October, 1911. (See Vol. 8 of the Proceedings, pp. 576 to 587.)

Motors.

718. Electric motors shall be of the standard commercial railway or mill type totally enclosed and made as weatherproof as practicable. They shall be mounted in such a manner as to admit of easy access for inspection and repairs. The frame, if practicable, shall be split so as to allow the top part to be removed for taking out the armature without disturbing the mounting of the motor. The motors shall be securely supported and anchored. There shall be a close fit of the anchor bolts in the holes. If installed on the moving span, they shall be capable of being operated satisfactorily in any position.

Tests.

719. Motors, circuit breakers, solenoids, brakes, and other electric mechanisms shall be tested at the factory by the manufacturer in the presence of the Company's inspector.

Temperature Rise.

720. Electrical parts, such as wires, switches, etc., shall be designed for the currents required for the motors when they exert the normal torques called for by the torque curves, on the supposition of continuous operation through successive cycles of bridge operation. For twice normal torques and 15 minutes of operation, the temperature rise of the parts shall not exceed that for continuous operation under normal torques. The excess torques shall be taken over successive cycles of bridge operation.

Working Plans.

721. The contractor shall make complete working plans for the electric equipment. These plans shall show:

a. Size of the wires.
b. Size and location of the conduits with number of wires in each conduit.
c. Size and location of the switchboard.
d. Location of the lamps.
e. Location of the controllers.
f. Size and location of resistances.
g. The numbering of the circuits corresponding to numbered tags.
h. A curve of the current required by the motors at the various stages of operation.

Special apparatus shall be designated by the manufacturer's name and catalog reference.

Number of Motors.

722. If the total power to move the bridge at the required speed exceeds 25 h. p., there shall be two main operating motors.

Motor Tests.

723. Any motor under test shall develop the required horsepower and torque at the armature shaft. Characteristic curves showing the results of the test shall be furnished by the manufacturer.

Starting Torque.

724. The sum of the starting torques of the motors shall be equal to at least twice the greatest torque shown by the torque curves for the bridge operating machinery. The pull out torque of alternating current motors shall be equal to at least 1¼ times the starting torque.

Speed of Motors.

725. The speed of motors of 20 h. p. and over shall not exceed 600 r. p. m. The speed of motors under 20 h. p. shall not exceed 900 r. p. m.

D. C. Motors.

726. Direct current motors shall preferably be of the railway series type with commutating poles. They shall be designed for the service characteristics specified. The normal brake horse power rating of each motor shall be based on the Standardization Rules of the American Institute of Electrical Engineers for railway motors. Each motor shall be capable of exerting continuously for four cycles twice the normal torque required for the moving span and machinery as shown on the torque curves, one cycle being understood to be the opening and closing of the bridge in the specified time. The temperature rise in any part of any motor after four complete cycles shall not exceed the allowable rise in accordance with the American Institute of Electrical Engineers' rating.

If the motors are used for dynamic braking, they shall perform this function without injurious sparking or temperature rise exceeding that specified above.

A. C. Motors.

727. Alternating current motors shall be of the induction type designed for the service characteristics specified. Those of more than 10 h. p. shall have slip rings. Each motor shall be capable of delivering its rated output continuously with a temperature rise not exceeding 40 degrees Centigrade in any part, and a 25 per cent. overload for two hours with a temperature rise not exceeding 55 degrees Centigrade, heat tests and temperature corrections to be in accordance with the Standardization Rules of the American Institute of Electrical Engineers.

Weather Protection.

728. The field and armature coils of motors shall be rendered moistureproof by treatment with a special compound. Motors outside of the machinery house shall be housed in a weatherproof metal housing. This housing shall be arranged to allow the motor to be inspected and oiled, and shall be readily removable. The metal in the housing shall be galvanized and not thinner than No. 16 U. S. Standard gage.

Motor Gears, etc.

729. In back-geared motors, one cast steel cut gear, bored and keyseated for attachment to the countershaft, shall be furnished with the motor. The gear and pinion shall be covered by a sheet steel or malleable iron split gear case, supported by the motor frame, and completely covering the gear and pinion. An opening with a hinged cover shall be provided in the gear case for inspection and oiling.

The r. p. m. of motors of 10-h. p. or more shall not exceed 700; the r. p. m. of the countershaft shall not exceed 125. For other motors, the r. p. m. shall not exceed 1000; that of the countershaft shall not exceed 200.

Spare Parts.

730. The Contractor shall furnish the following spare parts:

a. A set of fuses, not less than six of each kind.
b. A set of contacts and contact fingers for each device.
c. For each size of motor,
    One armature, or rotor,
    One field coil, or stator coil,
    One pinion and gear for back-geared motors,
    One set of brushes.
  These parts shall be fitted.

Controllers.

731. There shall be in the operating house one controller for the operation of the main motors, one for the rail lock motors, and one for the bridge lock motors. The controllers shall be so arranged that the operation of any motor may be cut out by pulling a switch on the switchboard, without affecting the operation of any other motor.

The controllers shall be of the reversing drum, or flat, type with magnetic blow-out. They shall be capable of varying and maintaining the speed of the motors throughout the entire range desired, without injurious sparking, and without shock due to sudden variation in speed. They shall be capable of doing their work for the normal loads, and for the excess loads that may come upon the motors, with a temperature rise not exceeding that specified for the motors.

732. The controller shall have a sufficient number of steps, such that the minimum or maximum motor torque will not differ by more than 10 per cent. from the average torque required for uniform acceleration.

For automatic control, there shall be no fewer than four points of acceleration. For manual control, there shall be no fewer than five points of acceleration. The manual control shall be of a type which will prevent the operator from throwing the controller handle quickly from the off to the fully on position.

733. The controller for the main motors, if for direct current, shall be of the series-parallel type. The field of interpole motors may be varied.

Resistances.

734. Rheostatic units shall be of the cast grid type, and of such capacity that the motor may be operated continuously at any point of the controller when developing normal torque, or for 15 minutes when developing excess torque, without sufficient rise in temperature of the resistance to cause deterioration of any part. The units shall be mounted on a steel frame so as to admit of free ventilation and to be without injurious vibration, and so that any unit or part of a unit may be removed and replaced without disturbing the others. The units shall be insulated from their supports.

Remote Control.

735. For currents of more than 400 amperes, the motors shall have remote control. The motor circuits shall be made by contactors mounted on panels or frames. The contactors shall be operated by solenoids which are controlled by a master controller.

Automatic and Remote Control.

736. The following features apply to remote and automatic control:

(a) *Controller Equipment.* The switchboard shall be made up of the necessary unit slate panels mounted on an angle iron frame.

Single or double pole shunt switches for reversing the motor shall be installed. A single pole magnetic shunt switch shall be provided for opening the side of the line opposite to that opened by the reversing switches.

A separate overload relay shall be provided to open each side of the line in case of overload or ground. The overload relays shall open both sides of the line. Upon tripping, they shall reset by bringing the master controller to the off point.

(b) *Master Controller.* Contacts and wiring parts of the master controller shall be easily removed and replaced. Controllers shall be provided with speed control.

The controller for direct current shall be of the automatic, reversing, magnetic contactor type with a separate, individual, series wound relay for each shunt wound acceleration contactor.

For parallel or series parallel operation, the controller shall have individual reversing switches and separate resistors for each motor with separate acceleration contactors controlled by one train of series wound acceleration relays, to prevent a direct path for current from one motor to the other.

(c) *Knife Switch.* A double pole, single throw, mill type, unfused, knife service switch shall be mounted on a switchboard.

A double pole, single throw, fused, knife switch for cutting off the control circuits shall be installed.

(d) *Series Switches.* Adjusting plugs, screws, or nuts shall be stationary and easily accessible so as to allow the series switches to be adjusted for closing value while the controller is running.

(e) *Interlocks.* The reverse shunt switches shall be mechanically interlocked preventing the closure of the reverse switches until the forward switches have opened. The reverse switches and the series switches shall be electrically interlocked preventing the closure of the reversing switches while the forward switches or any series switch is closed.

(f) *Contacts.* Contacts on both the shunt and series switches shall be removable without dissembling any other part of the switch.

Brakes.

737. The main motors, rail lock motors, and bridge lock motors shall be provided with approved post brakes which are held in the set

position by a spring with such force as to overcome at least half of the maximum torque required. The friction surfaces shall be of materials which are not affected by moisture. The brakes for main motors shall be arranged to be released by shunt coil solenoids; brakes for other motors by series coil solenoids. The solenoids shall have ample power and heating capacity whenever the motors are taking current, and shall be set automatically whenever the current fails or is cut off from the motors. Series brakes shall be dry brakes. Moistureproof motors shall be provided with moistureproof solenoids. Brakes on main operating motors shall be provided with a foot-switch release for coasting purposes. Means shall be provided for releasing the brakes mechanically.

Air Brakes.

738. If air brakes are used, they shall be controlled from the operator's house. The air compressor shall be able to compress at least 11 cu. ft. of free air per minute against a tank pressure of 90 pounds per square inch. The loss of pressure shall not be more than 1½ pounds in 10 minutes.

The air tank shall be 22½ inches in diameter and 42 inches long or of equal capacity. It shall be built up of boiler plate with a riveted lap longitudinal joint and concave ends welded into place. It shall show no leaks when tested at 160 pounds pressure. The working pressure of the tank shall be 60 pounds minimum and 90 pounds maximum.

The brake cylinder shall have a spring release capable of placing the brake in the released position automatically as soon as the air is exhausted to the atmosphere. The cylinder shall not be less than 6 inches in diameter and have not more than a 6 inch stroke.

At a convenient place in the line carrying air to the brake cylinder, there shall be a union with a choke which will introduce a time element of 5 seconds between the operating lever and the action of the cylinder.

If the control of the air to the brake cylinder is remote and electrically operated, the arrangement of the application and release magnets shall be such that the brake will be applied in case of any voltage failure.

The pipe line between the compressor and the reservoir tank shall contain not less than fifty feet of pipe. From the compressor it shall run vertically upward to the highest point in the line. From this point the line shall slope downward to the tank.

Emergency Brake.

739. The emergency brake shall be arranged to be released by solenoids or motors which will hold the brake in release as long as the current is applied to the brake motor. Cutting off the current from the solenoids or motors, or any failure of the current shall result in the instantaneous application of the brake. This brake normally shall be set and arranged so that it must be released by the operator before starting the bridge. It shall be held in release during the entire opera-

tion unless an emergency condition arises requiring brake power in excess of that offered by the motor brakes, in which case it may be applied instantly by the operator. This portion of the equipment shall be so designed that it will not be injured if left in release indefinitely. Means shall be provided for releasing the emergency brake mechanically.

740. The emergency brake motor circuit shall be independent of the general interlocking system, and there shall be a mechanical interlocking device which will prevent the main operating motors and the emergency brake being used one against the other, except at the instant of closing. At closing the brake shall be automatically applied (before the power is cut off from the main motors) to prevent rebounding of the span.

741. The emergency brake switch shall be attached to the controller stand within easy reach of the operator. Labels shall be placed back of the switch handle to indicate set and released positions of the brake.

Brake Housing.

742. Solenoid and motor-operated brakes shall be housed.

Automatic Stops.

743. The bridge lock motors and the rail lock motors shall be arranged to be stopped and their brakes to be set automatically at each end of the travel. An automatic cut-off shall be provided which will cut off the current and set the brakes so that the span will be stopped when the end is 6 feet from the fully closed or fully open position. Spring switches shall be provided, which, if held closed, will put the cut-off out of service and thus enable the bridge operator to close or fully open the bridge.

Switchboard.

744. The switches, cut-outs, circuit breakers, fuses, and meters shall be mounted on an oil finished slate panel switchboard, not less than 1½ inches thick and free from metallic veins and flaws, in the operator's house. The bottom of the board shall clear the floor by at least 9 inches. There shall be a distance of at least two feet between the wall and any of the parts on the back of the switchboard. The appliances mounted on the switchboard shall be provided with plates designating their uses.

Meters—Ground Detector.

745. A volt meter and ammeter and a watt-hour meter shall be provided on the switchboard. The switchboard instruments shall be furnished with illuminated dials. There shall be a switch connecting the volt meter to the mains or from either main to the ground.

Switches.

746. There shall be a switch of the quick break type for each supply wire and a switch, approved by the Engineer, in each motor circuit and each light, signal, indicator, or other circuit.

Circuit Breakers and Fuses.

747. An automatic circuit breaker shall be placed in the feed wires. There shall be in each line to a motor, each line to an electric brake, and each lighting, signal, indicator, or other circuit, an enclosed fuse with knife blade contacts.

Emergency Switches.

748. Emergency switches which will free the various motors from the interlocking in emergency shall be mounted on the switchboard, covered by sealed glass cases.

Feeder Protection.

749. The feeders shall be protected by a switch, an enclosed fuse, and a lightning arrester, mounted on a non-combustible and non-absorbent insulating base. The connection for the lightning arrester shall be a No. 4 B. & S. gage wire run in a direct line to a ground plate, and not connected to any structural part. To avoid inductance, the wires shall be in a split conduit. If a choke coil is used, it shall be insulated from the ground and from other conductors.

Switches.

750. Switches shall be designed to carry not more than 900 amperes per square inch of cross section. Knife switches shall have not less than 100 amperes capacity. The blades or clips of knife switches and similar parts shall be not less than $\frac{3}{32}$ inch thick. Snap switches shall not be installed in circuits carrying more than 6 amperes. They shall be of not less than 20 amperes capacity.

Preferably, laminated switches shall not be used, but if used they shall have auxiliary carbon contacts which operate later.

A magnetic blow-out shall be used with large switches.

Contact Areas.

751. Line contact in a circuit shall be avoided wherever practicable. The current per square inch of contact area shall not exceed 50 amperes for loose contact, or 100 amperes for bolted or clamped contact.

Circuit Breakers.

752. Circuit breakers and fuses shall be designed to open the circuit when the motors are taking 10 per cent. more than the current required to develop twice the greatest normal torque.

Circuit breakers shall have not less than two poles, with a common trip, overload attachments, and a no-voltage release. There shall be individual closing arms for each pole. There shall be an overload coil in each line for direct current circuits, and in each of two lines of a three phase, three wire circuit. Tripping attachments shall be positive in action.

Circuit breakers of the no-voltage or the shunt-trip types shall not be used for limiting the travel of any mechanism.

Phase Failure Device.

753. For alternating current, three phase power, a phase failure device shall be provided which will open all three phases when any phase fails.

Ground Connections.

754. Ground connections of ample area shall be installed.

Protection of Contacts.

755. Electrical contacts shall be protected from the weather and accumulations of dirt.

Metal Covers.

756. Metal coverings for drum switches and similar parts shall be of not less than No. 18 U. S. Standard gage. For built-up boxes, the metal shall be of not less than No. 14 U. S. Standard gage. Junction boxes shall preferably be made of malleable cast iron not less than $\frac{3}{16}$ inch thick, which will allow the conduits to be threaded into the box. The boxes must be weatherproof throughout, in particular at conduit connections, and be free from rough edges and rough surfaces.

Cast Iron in Electrical Parts.

757. Cast iron, unless malleable, shall not be used in switches and small electrical parts which are located on the bridge.

Wires.

758. Stranded wires shall not be smaller than No. 10 B. & S. gage. Circuits to motors and all circuits running on the moving span shall be of stranded wire throughout. Solid wire of not less than No. 12 B. & S. gage, may be used for other circuits.

Splices.

759. Splices shall be neatly and carefully made. They shall be made mechanically and electrically secure before soldering. Splices shall not be inside of a conduit.

Conduits.

760. Wires shall be placed in metal conduits. The combined area of the wires (including insulation) in any conduit shall not exceed 42 per cent. of the area of the conduit.

To lessen the inductive effects, the phase wires in alternating current circuits shall be placed close together in one conduit. Not more than three alternating current circuits shall be in one conduit. A circuit in three phase work means three wires.

Conduits shall be sherardized or loricated on the inside and outside. Sherardized or loricated conduits, pull-out boxes, ells, and other fittings shall be used in connection with conduits. Bends shall be used sparingly. The radius of the bend to the center of the conduit shall not be less than six times the inside diameter of the conduit. Junction boxes may be used where other fittings are not suitable. Conduits and boxes shall have suitably located drain holes.

Conduits shall be placed so that dirt will not accumulate around them. There shall be at least one-half inch clearance between them. If on top of a horizontal surface, they shall clear the surface by at least three inches.

Flexible Connections.

761. At points where stationary conduits join the conduits on the moving span, flexible connections shall be installed. The flexible connections shall be connected at each end by combination couplings to junction boxes with slate terminal boards. If the flexible connections are 15 feet or less in length, the wires shall be in flexible metal conduits; if more than 15 feet in length, the flexible connections shall be made of built-up cables with provision for carrying the weight of the wires and for mechanical protection of the wires.

Wires to be Tagged.

762. Wires shall be permanently tagged with metal tags and numbered so that any wire may be traced from the switchboard to the motor or to the source of power.

Supply Cables.

763. If the current supply is obtained from more than one source, the cables shall be separated to prevent grounds or short circuits in one cable from injuring the remaining cables. Each cable shall have capacity to carry the maximum current required to operate the bridge.

Collector Rings.

764. Collector rings shall be protected from weather and accumulation of dirt by suitable guards, which will also protect workmen.

T Rail Conductors.

765. In vertical lift bridges, the current shall be conveyed to the span through a T rail weighing not less than five pounds a foot and having a copper contact strip. Against this rail a sliding shoe shall be pressed by a spring or by gravity.

Submarine Cables.

766. Submarine cables shall be placed at least five feet below the bed of the navigable channel. The current and voltage for which the cable is to be used, the number of conductors in the cable, the size and number of strands in each conductor, the length of the cable, and other data special to the location shall be as specified by the Company for each bridge.

Indicators.

767. The Contractor shall furnish and install in the operator's house, electric light indicators which will show to the operator the various positions of the bridge, especially the fully open, entirely closed, nearly open,

and nearly closed positions of the bridge, and the closed and open positions of the end lifts, rail locks, and bridge locks.

Lighting.

768. A complete electric lighting system shall be installed for the operator's house, stairways, signals, etc. The system shall be designed and proportioned for the electric lighting service available. Wires shall be run in metal conduits.

In the operator's house, there shall be pendant drop cords of suitable length with cord adjusters, brass key sockets, and deep cone fire enameled steel shades. For exterior lighting, deep bowl, fire enameled steel reflectors and weatherproof sockets shall be provided. The Company will furnish at the site one complete set of lamps. The Contractor shall place them in the lamp sockets and shall be responsible for them until the acceptance of the work by the Engineer.

Circuits.

769. Circuits are classified as follows:

1. Circuits for main motors.
2. " " bridge lock or end lift motors.
3. " " rail lock motors.
4. " " lighting.

Class 4 is divided into the following groups for lamps:

a. Lamps for operator's house.
b. " " stairways, walks, etc.
c. " " machinery.
d. " " navigation and indicators.

There shall be an independent circuit for each motor and each group of lamps. Each circuit shall be independent of the other circuits; the use of a common return wire will not be allowed. Each circuit shall be protected and controlled by its own fuses and switches. A circuit in three phase work means three wires.

Magnetic Switches.

770. Where magnetic switches are used, overload relays, electrically and hand reset, shall be used for overload protection. Magnetic switches shall be quick acting, with magnetic blow-outs and wiping contacts well shielded to prevent arcing between the switch and other metal parts near. The switches shall have a minimum number of parts. Series magnetic switches shall not be used to break a current on opening.

Shunt Coils.

771. If shunt coils are used, in particular with brakes and magnetic switches, the insulation shall be such as to withstand the induced voltage caused by cutting off the current without the aid of external resistance. As a further precaution, external resistance shall also be used, in particular in brakes.

8. MATERIALS.

a. *Cast Steel.*

Cast Steel.

801. Steel for castings shall conform to the General Specifications for Steel Railway Bridges of the American Railway Engineering Association, except as may be herein modified.

A test to destruction on three castings selected from a lot may be substituted for the tensile test, in the case of small or unimportant castings. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from the same melt or blow annealed in the same furnace charge.

Large castings shall be hammered all over while suspended. If cracks, flaws, defects, or weaknesses appear after such treatment, the casting shall be rejected.

b. *Forged Steel.*

Forged Steel.

802. Steel for forgings shall be made by the open hearth or the crucible process and shall conform to the following chemical requirements:

Phosphorus, maximum ....0.04 per cent.
Sulphur, maximum ....0.05 per cent.

An analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt. Check analyses may be made by the purchaser from drillings taken from, (a), a full-sized prolongation of a forging from each melt at a point midway between center and surface, or (b), turnings from a test specimen. Both analyses shall conform to the requirements specified.

803. The following physical properties are required:

Ultimate tensile strength in lbs. per sq. in. 55000 to 65000.
Minimum elongation, per cent. in 2 in............... 20.
Yield point...............................one-half of ultimate.

The tension test shall be made on a standard turned test specimen, ½ inch in diameter and 2 inches in gaged length.

804. A specimen 1 inch by ½ inch, shall bend cold 180 degrees around a diameter of ½ inch without cracking on the outside of the bend. The bending may be effected by pressure or by blows.

805. Forgings shall be free from cracks, flaws, seams, and other injurious defects.

806. Forgings shall be annealed. Before annealing, the forgings shall be allowed to become cold after forging. They shall then be reheated uniformly to the proper temperature and allowed to cool uniformly.

807. Physical tests of forgings shall be made after final treatment. Each annealing charge and each melt shall be tested.

If the tests do not show the required physical properties, the forgings may be reannealed, but not more than three times. If the tension specimen shows a fracture more than 15 per cent. crystalline, a second test shall be made. If the second fracture is more than 15 per cent. crystalline, the forgings shall be reannealed.

808. Test specimens shall be cut cold from the forging or a full-sized prolongation of it. For forgings with large ends or collars, the test specimen shall be taken from a prolongation of the same diameter or cross section as that of the forging back of the large end or collar. The axis of the specimen shall be half-way between the center and the outside, or for hollow forgings, half-way between the inner and outer surfaces. The length of the specimen shall be in the direction of the working or drawing out of the metal. Marks identifying the melt and annealing charge shall be stamped on each forging and on each test specimen by the Inspector before the specimen is cut.

c. *Tool Steel.*

Tool Steel.

809. Tool steel shall be made by the open-hearth or the crucible process. It shall conform to the following chemical requirements:

Carbon, minimum	1.00	per	cent.
Phosphorus, maximum	0.04	"	"
Sulphur, maximum	0.04	"	"
Manganese, maximum	0.50	"	"

d. *Bronzes.*

810. Phosphor bronze shall be a homogeneous alloy of crystalline structure. It shall be made from new metals, except that scrap of known composition produced by the foundry at which the bronze is cast may be used. It shall not contain sulphur. The phosphorus shall be introduced in the form of phosphor-tin or phosphor-copper. Castings shall be sound, clean, and free from blow-holes, porous places, cracks, and other defects.

811. The hardness of the finished castings shall be tested by the Brinell ball method and a record of the test furnished. The ball shall be of hardened steel 10 mm. in diameter. The load shall be 500 kg. and shall be applied for 30 seconds to a finished plane surface. At least two hardness tests shall be made upon each heat. A test shall be made on each trunnion bearing and each disc.

812. The alloy shall be cast into ingots and allowed to cool, and the castings shall be poured from the remelted ingots. Care shall be exercised that the metal is not overheated and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

813. There shall be four grades.

Grade A is to be used for contact with hardened steel discs under pressures exceeding 1500 pounds per square inch, such as are used in turntables and center bearing swing bridges.

Grade B is to be used for contact with soft steel at low speeds under pressures not exceeding 1500 pounds per square inch, such as trunnions and journals of bascule and lift bridges.

Grade C is to be used for ordinary machinery bearings.

Grade D is to be used for gears, worm wheels, nuts, and similar parts which are subjected to other than compressive stresses.

814. The chemical and physical qualities shall conform with the requirements in the following table:

ALLOY OF	GRADE			
	A	B	C	D
	Copper and tin	Copper and tin	Copper, tin and lead	Copper, tin and zinc
Copper per cent			82 max.	82 max.
Tin per cent	20 max.	17 max.	11 max.	11 max.
Lead per cent			11 max.	
Zinc per cent				2.25 max
Phosphorus per cent	1.0 max.	1.0 max.	1.0 max. 0.7 min.	0.25 max.
Other elements per cent	0.5 max.	0.5 max.	0.5 max.	0.5 max.
Elastic limit in compression, pounds per square inch	24000 min.	18000 min.		
Permanent set in inches under 100,000 pounds	.06 min. .10 max.	.10 min. .20 max.		
Permanent set in inches under 50,000 pounds	To be recorded	To be recorded	To be recorded	To be recorded
Yield point in tension, pounds per square inch				To be recorded
Ultimate strength in tension, pounds per sq.in.				33000 min.
Elongation in 2 inches per cent				14 min.

Cracks or other evidence of excessive brittleness in compression test specimens after load may be cause for rejection.

The chemical analysis of each heat shall be furnished.

815. Test specimens shall be made from coupons which are a part of the casting and which have been fed and cooled under the same conditions as the casting.

Compression test specimens shall be cylinders one inch high and of one square inch area. The elastic limit in compression shall be the load which gives a permanent set of 0.001 inch.

Tension test specimens shall be turned from a coupon not less than one inch in diameter to the form shown in Fig. 2 of the American Railway Engineering Association General Specifications for Steel Railway Bridges. The diameter of the turned specimen shall be one-half inch.

816. At least one compression test shall be made from each melt for grades A, B, and C; and one compression and one tension test for grade D. For castings weighing over 100 pounds, finished, the prescribed tests shall be made for each casting.

e. *Babbitt Metal.*

Babbitt Metal.

817. Babbitt metal shall be of the following composition:

Copper	3.6 per cent.
Tin	89.3 per cent.
Antimony	7.1 per cent.

9. ERECTION.

Protection of Parts.

901. Parts which are protected from the weather in the finished structure shall be protected in the field during erection by housing or equivalent means. This applies in particular to electrical parts.

902. Rubbing surfaces of trunnions and machinery bearings shall be protected by metal thimbles packed with oil-soaked waste.

903. Wire ropes shall be housed and stored at least 18 inches above the ground. The ropes shall be kept free from dirt, cinders, and sand. During erection, the ropes shall not be pulled through dirt, or bent into sharp angles or kinks.

Lubrication.

904. The Contractor, during erection, in particular just before the final test, shall lubricate the sliding parts and fill all grease cups. The counterweight ropes and the operating ropes shall be given two coats of dressing with an interval of one month between the coats. The dressing shall not be applied in an atmospheric temperature below 40 degrees F.

Channel Lights.

905. During erection, or in taking down the old span, the Contractor shall place and maintain navigation lights and signals, in accordance with the Government requirements, for the protection of the falsework, as well as navigation.

Erection of Machinery.

906. The machinery shall be erected by skilled machinists. Special care shall be given to the alinement of trunnion bearings.

Testing of Machinery.

907. Before the main operating machinery is connected for transmitting power, it shall be given either a continuous idle run of 50 hours, or five runs each of 10 hours' duration. Any defects shall be remedied.

The bridge shall be operated to the fully closed and to the fully open position in the normal time of opening at least 10 times before it is put into service.

Bridge Operator.

908. After a power-operated structure has been tested and accepted, the Contractor shall provide, at his own expense, a competent man to operate the bridge for a period of sixty days. This operator shall instruct the employees of the Company in the operation of the bridge.

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Appendix E.

STRESSES IN WIRE ROPES.

DISCUSSION OF THE REPORT OF COMMITTEE XV.

By DR. J. A. L. WADDELL, Consulting Engineer.

Wire ropes are used in movable bridges for two decidedly different classes of service:

(a) Suspending Ropes for Counterweights.
(b) Operating Ropes.

The counterweight ropes are practically a part of the permanent structural work of the bridge. As their replacement is somewhat difficult, at least for large and important structures, they should be so designed as to have a long life; and as the consequence of breakage might be very serious, they should have a large margin of safety. The operating ropes, on the other hand, are strictly a portion of the machinery equipment. Since they can be replaced with comparative ease, long life is not so essential in their case. Also, for vertical lift spans—with which type of span they are mostly used—they do not need an unusually large margin of safety, as a failure would do comparatively little damage.

Wire ropes are subjected to two main kinds of stresses: direct stresses, and bending stresses due to passing over sheaves or drums. Direct stresses have little effect on the life of a rope, provided that the ratio of the ultimate strength to the direct stress exceeds four; although, of course, the larger the safety factor the smaller is the danger of a badly worn rope's breaking. The bending stresses, on the other hand, determine directly the life of the rope. The failure of a rope from this cause is a very gradual one, individual wires snapping one by one over a considerable period of time, until the strength of the rope is so much reduced that the direct stress causes the remaining wires to break. Abrasion of the wires, due to wear on the sheaves and rubbing on each other, is a contributing cause. Since the failure due to bending is thus a very slow one, there is little danger of the complete breakage of a rope which receives a reasonable amount of inspection, provided the safety factor as regards direct stress exceeds four. In conservative commercial usage, which assumes that inspection is regular and that replacement is a simple matter, the ratio of ultimate strength to the static direct load has usually ranged from five to ten, the smaller value being used when stresses due to acceleration, impact, and shock are small, and the latter when they are very large; while the ratio of sheave diameter to rope diameter has been made large enough to insure a safe life of two or three years. For 6 x 19 steel hoisting ropes, the value of this latter ratio has usually ranged from 32 to 48, with values of 60 or more for high speed rope drives in constant service. The reason for the large ratios with the high speed work is apparent; for if such a rope is to last for two or three years in spite of the large number of bends that it makes, the bending effect must be kept quite small.

In ordinary practice in the past little attention has been paid to the actual maximum unit stresses in ropes, for proper consideration of the safety factor as regards direct stress and of the ratio of sheave diameter to rope diameter has been found to insure safe and satisfactory service. Many of the best wire rope engineers have followed these designing methods. It hardly appears logical, however, to fail to take into account the maximum unit stresses, and modern rope design is considering it more and more. A serious difficulty has been the uncertainty as to the bending unit stresses, which, obviously, cannot be measured directly. By far the best contribution to this subject is a paper, "The Stress in Wire Rope Due to Bending," by R. W. Chapman, published originally in the 1908 Proc. Australian Inst. of Mining Engineers, and reprinted in October, 1908, in the Engineering Review of London. In this paper Mr. Chapman discusses several proposed formulas and points out their inconsistencies, and then proceeds to develop a formula which appears to be mathematically correct. He also checked his results to a certain extent by experiment. Mr. Chapman assumes the individual wires to bend separately, and takes into account the angles of lay of the helical wires in each strand and of the helical strands in the rope. His formula is:

$$f_b = \frac{Ed \cos^2 L \cos^2 B}{D}, \text{ in which}$$

f_b = unit stress due to bending.

E = Coefficient of elasticity of the metal,
= 28,500,000 for iron or steel ropes,
d = Diameter of largest individual wire,
D = Diameter of sheave,
L = angle of lay of helical wire in the strand,
B = angle of lay of helical strand in the rope.

Consider now the 6 x 19 hoisting rope, which is the only form of rope permitted by the specifications. The average angle of lay of the helical strands in the rope is about 19° for which the square of the cosine is 0.89. For the helical wires, the angle of lay of the central wire is 0°, with a cosine squared of 1.00: that of the first row of wires is about 9°-30′, with a cosine squared of 0.97; and that of the outer row of wires is about 18°-30′, with a cosine squared of 0.9. There are two ordinary forms of rope construction. In the standard one-size-wire construction, the diameter of each wire is about 1/15 of the diameter of the rope; in the Warrington lay rope, the central wire and the row of 6 wires surrounding it are each 1/15 of the rope diameter; while the twelve wires in the outer row are alternatively large and small, the diameter of the larger wires being about 1/13.2 of the rope diameter, and that of the smaller wires about 1/18.5 of the rope diameter. Letting the diameter of the rope be C, we have, on substituting in Mr. Chapman's formula:

One-size-wire construction:

Center wire of strand

$$f_b = \frac{28500000 \times C \times 0.89}{15\,D} = 1900000\frac{C}{D} \times 0.89 = 1690000\frac{C}{D}$$

First row of wires

$$f_b = 1900000 \times \frac{C}{D} \times 0.89 \times 0.97 = 1640000\frac{C}{D}$$

Outer row of wires

$$f_b = 1900000 \times \frac{C}{D} \times 0.89 \times 0.9 = 1520000\frac{C}{D}$$

Warrington Lay:

Center wire of strand $= 1690000\frac{C}{D}$

First row of wires $= 1640000\frac{C}{D}$

Large wires in outer row

$$f_b = \frac{28500000 \times C \times 0.89 \times 0.9}{13.2\,D} = 1730000\frac{C}{D}$$

As an average value applicable to the different types of rope and the different wires in the rope, we can use

$$f_b = 1700000\frac{C}{D}.$$

The metallic area of the one-size-wire rope, since $d = \frac{C}{15}$, is $0.398C^2$ or say $0.4C^2$. The area of the Warrington lay rope is practically the same as that of the one-size-wire rope.

The actual areas of wire ropes do not follow exactly any regular law and there is more or less variation among different manufacturers; but the value of $0.4C^2$ gives good average values, and accordingly has been adopted for the specifications. In determining the table of total ultimate strengths and unit ultimate strengths for the specifications, a regularly decreasing series of unit stresses was selected, by trial, so as to give, when multiplied by the areas $0.4C^2$, values which would agree as closely as possible with the ultimate strengths given in the manufacturers' handbooks for standard plow-steel hoisting ropes. Each of the large manufacturers makes also an extra strong plow-steel rope, but it was thought best to consider only the standard plow-steel ropes in the specifications.

In determining the safety factor as regards the direct stress plus bending stress, it is necessary, of course, to consider the ordinary commercial practice previously mentioned. For a 6 x 19 standard plow-steel rope, with a safety factor of five as regards direct stress only, the safety factor as regards direct stress plus bending stress is about 2 for a ratio of 32 for sheave diameter to rope diameter, 2.5 for a ratio of 48, and 2.8 for a ratio of 60. With a safety factor of six as regards direct stress only, which represents very conservative practice when there is no great amount of shock, the corresponding values are 2.2, 2.8, and 3.1. A sheave ratio of only 32 is too small for first-class work, and eliminating those values, the safety factors are from 2.5 to 3.1. Evidently, therefore, a safety factor of 3 as regards direct stress plus bending stress will be quite conservative, and will insure that the rope will be safe and will have a long life even for such steady service as elevator or mine hoisting work. In the specifications, this value has been adopted for the operating ropes; and in order to prevent the possible use of small sheaves or drums, it is provided that the ratio of sheave diameter to rope diameter shall not be less than 45. Operating ropes thus designed will evidently last for many years, even under very heavy service, as no bridge will receive anything like as many operations per day as will an elevator.

Counterweight ropes, if designed under the specifications for the operating ropes, would probably wear out after a good many years service, and thus need renewal. While there would be no real danger from this cause, because of the gradual nature of the failure of ropes, it nevertheless would indicate that the factor of safety was rather small. In view of this fact, the Committee has decided to make the factor of safety as regards direct plus bending stress 5, and to require that the sheave diameter shall be at least 80 times the rope diameter, and preferably not less than 90 times. These requirements may appear somwhat excessive, in view of ordinary practice; but the Committee has preferred to err on the side of safety, especially as the total cost of a movable span will not be increased unduly thereby.

The most important use of wire rope for movable bridges has been in the cable type of vertical lift bridge, of which a large number have been designed. Table 1 shows the safety factors and ratios of sheave diameters to rope diameters for the counterweight and operating ropes of a number of these structures.

The only structure in this list which has been in service long enough to give conclusive evidence concerning the ropes is the Halsted Street Bridge, which is now about 24 years old, and which has been operated some 3000 times per year. The original counterweight ropes are still in use, and are in good condition. From this structure it is apparent that the proposed wire-rope-specifications for counterweight ropes are sufficiently conservative.

The writer, from his experience, believes that his past practice in wire rope design has been conservative enough. He considers that the following requirements would certainly be sufficiently severe:

Counterweight Ropes:

$$\frac{\text{Ultimate Strength}}{\text{Direct Stress}} = 7 \text{ to } 8.$$

$$\frac{\text{Ultimate Strength}}{\text{Total Stress}} = 3.5 \text{ to } 4.$$

$$\frac{\text{Sheave Diameter}}{\text{Rope Diameter}} = 60 \text{ to } 80.$$

Operating Ropes:

$$\frac{\text{Ultimate Strength}}{\text{Direct Stress}} = 5 \text{ to } 6.$$

$$\frac{\text{Ultimate Strength}}{\text{Total Stress}} = 2.5 \text{ to } 3.$$

$$\frac{\text{Sheave Diameter}}{\text{Rope Diameter}} = 40 \text{ to } 48.$$

The first values are to be used for ordinary structures which are not operated a great deal, while the latter apply for important structures which open very frequently.

TABLE 1—DATA ON WIRE ROPES OF VERTICAL LIFT BRIDGES.

Name of Bridge	Span Length Ft.	Weight of Span Lbs.	Date Completed	Counterweight Ropes					Operating Ropes				
				Sheave Diam.	Ropes per Corner	Ratio Sh. Dia. to Rope Dia.	Safety Factors		Sheave Diam.	Rope Diam.	Ratio Sh. Dia. to Rope Dia.	Safety Factors	
							Ultimate / Direct	Ultimate / Total				Ultimate / Direct	Ultimate / Total
Halsted	130′	580000#	1894	144"	8-1½"	96	9.5	4.9	....	⅞"	....	....	....
Keithsburg-Miss. R.	230′	940000	1910	96"	8-1⅝"	60	6.4	3.2	30"	¾"	40	4.5	2.2
Sand Point	83′	60000	1910	42"	2- ⅞"	48	9.4	3.2	15"	⅜"	40	30.0	3.6
Hawthorne Ave.	244′	1770000	1910	108"	12-1½"	72	4.6	2.9	40"	1"	40	4.6	2.3
Fratt-Mo. River	425′	1470000	1911	60"	12-1½"	40	6.6	2.6	....	....	....	....	....
				48"	4-1⅛"	43	7.6	2.9	....	....	....	....	....
Tehama	167′	270000	1911	60"	4-1⅛"	53	6.6	2.4	22"	⅜"	59	5.0	3.1
Big Choctaw Bayou	50′	70000	1911	54"	2-1"	54	9.3	3.6	18"	½"	36	28.8	4.0
Arkansas River	192′	1500000	1912	108"	8-1⅞"	58	5.6	2 9	36"	¾"	48	3.0	1.9
O. W. R. R. & N., Up. Deck	211′	3420000	1912	168"	16-2¼"	75	6.9	3.6	48"	1⅛"	43	3.5	1.8
O. W. R. R. & N., Low. Deck	211′	1060000	1912	76"	14-1¼"	61	7.7	3.4	76"	....	....	....	....
Salem-Willamette River	131′	460000	1913	84"	8-1¼"	67	8.4	3.9	24"	¾"	32	10.8	2.7
Illinois River	173′	700000	1913	102"	8-1½"	68	7.7	3.7	30"	¾"	40	8.2	2.9
St. Paul-Miss. River	189′	850000	1913	108"	8-1⅝"	66	7.5	3.6	24"	¾"	32	6.2	2.3
City Waterway	214′	1640000	1913	108"	16-1½"	72	6.7	3.0	40"	1"	40	4.1	2.2
Puyallup Waterway	161′	940000	1913	108"	8-1¾"	62	7.8	3.5	36"	⅞"	41	5.5	2.5
Trail-Columbia River	171′	270000	1913	76"	4-1⅛"	68	6.1	3.3	22"	½"	44	11.6	3.6
St. Francis River	162′	620000	1913	96"	8-1⅜"	70	7.6	3.8	24"	¾"	32	7.8	2.5
Little River	118′	380000	1913	76"	8-1⅛"	68	8.5	4.0	24"	¾"	32	13.4	2.8
Black River	165′	620000	1913	96"	8-1⅜"	70	7.6	3.8	24"	¾"	32	8.6	2.5
C. N. P. No. 10	90′	240000	1913	76"	4-1¼"	61	8.2	3.6	18"	⅝"	29	18.8	2.9
Mo. River, G. N. Ry.	296′	1560000	1914	144"	8-2⅛"	68	6.9	3.5	30"	⅞"	34	4.7	2.1
Yellowstone River Gr. Nor. Ry.	271′	1370000	1914	132"	8-2"	66	6.9	3.4	30"	⅞"	34	5.2	2.2
Penna. Calumet River	210′	1840000	1914	180"	12-2⅛"	85	8.2	4.2	40"	1"	40	4.6	2.3
Penna. Chicago River	273′	3000000	1914	180"	16-2¼"	80	7.8	4.0	48"	1⅛"	43	6.0	2.7
Caddo Lake	92′	220000	1914	76"	4-1"	76	5.9	3.4	24"	⅝"	38	24.5	3.8
Oromocto	58′	150000	1915	76"	4-1"	76	9.7	4.3	30"	¾"	40	39.5	4.0
L. S. & M. S. Calumet River	210′	1410000	1915	180"	12-2"	90	10.1	4.8	46"	¾"	61	9.8	4.0
									46"	1½"	31	18.9	7.7
Harrisburg	200′	660000	1915	96"	8-1½"	64	8.5	3.8	24"	1"	24	10.2	3.1
Pac. Hy. Columbia Riv.	272′	2400000	1916	144"	16-2"	72	7.2	3.7	36"	1¼"	29	5.8	2.5
Don River-Russia	210′	1600000	1917	138"	16-1¾"	79	9.2	4.3	40"	1"	40	4.4	2.2

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NINETEENTH ANNUAL CONVENTION
Congress Hotel, Chicago
March 19, 20, 21, 1918

BULLETIN
OF THE
American Railway Engineering Association

Vol. 19, No. 205 . . . . . March, 1918

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OF THE
Special Committee on Stresses in Railroad Track

Report on Wood Preservation

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BULLETIN

OF THE

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Progress Report of the Special Committee on Stresses in Railroad Track

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Report on Wood Preservation

W. D. PENCE, *Editor.*
Chicago, Ill.

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910 Michigan Avenue,
Chicago, Ill.

American Railway Engineering Association

VOL. 19, No. 205 . . . . MARCH, 1918

NINETEENTH ANNUAL CONVENTION

Chicago, March 19, 20, and 21, 1918

PROGRAM.

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Election and Installation of Officers.

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PROGRESS REPORT

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1918

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PROGRESS REPORT OF THE SPECIAL COMMITTEE ON STRESSES IN TRACK.

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To the American Railway Engineering Association:

The Special Committee on Stresses in Track herewith presents a progress report.

(I) INTRODUCTION.

1. *Preliminary.*—The Committee was formed by action of the Board of Direction November 20, 1913. A similar committee, the Special Committee to Report on Stresses in Railroad Track, was created by the Board of Direction of the American Society of Civil Engineers November 12, 1913. In each case authority was given to co-operate with the Committee of the other Society. The Committee of the American Railway Engineering Association is identical with that of the Special Committee of the American Society of Civil Engineers, except that it contains five members who do not hold membership in the American Society of Civil Engineers and are not on the Committee of that Society. The Committee of the American Society of Civil Engineers and that of the American Railway Engineering Association, under the authorization given, have in effect carried on their work as a single committee. This report is presented simultaneously to the two Societies.

The Board of Direction of the American Society of Civil Engineers made an assignment of funds for the work of the Committee March 4, 1914, and a contribution toward the expenses of the tests was received by the American Railway Engineering Association a few days later. Funds having been provided to make a beginning, the initial meeting of the Committee was held in Chicago March 18, 1914, when the field of the work and the manner of undertaking it were discussed. At a meeting in Baltimore June 3, 1914, the report of a Sub-Committee on Organization and Scope of Work was adopted. Mr. W. M. Dawley was made Vice-Chairman of the co-operating committees, and Mr. E. H. Fritch, Secretary of the American Railway Engineering Association, was elected Secretary. Preliminary field work was begun in the summer of 1914, and apparatus and methods of testing were developed as fast as experience could be gained. The work in field, laboratory and office has since been carried on as actively as the conditions would warrant. Progress reports of the experimental work have been made to the Committee from time to time and the results of the tests have been discussed at committee meetings and by correspondence. A great deal of time has been consumed in working up the results and in putting the data in form for presentation.

From the beginning the Committee has appreciated that the problem assigned to it is very complicated, involving many difficulties and uncertainties. It has felt that an adequate report on stresses in railroad track must be based upon experimental data derived from extensive tests on standard railroad track. It has also appreciated that because of the complexity of the action of track under load and the variability of the conditions which may be found in track and load, adequate experimental work would involve long, painstaking, and repeated tests under many conditions and also that considerable time would be required for reducing the data so obtained and for interpreting the results. It is believed that results of value could be obtained only after prolonged work on the problem. Experience has shown that the anticipated difficulties were not overestimated. It was found necessary to expend a considerable amount of effort and considerable time on the development of instruments for use in the tests and on methods for conducting tests. The problem was studied and the methods developed in the light of the information gained during the work. The experimental work undertaken so far has included the measurement of track depressions, ballast and roadway pressure, and fiber stress in rail, for both static loads and moving loads, and laboratory tests on the distribution of pressure through ballast.

It is noteworthy that notwithstanding the importance of track relatively few experimental data on the general action of the track structure are on record and available as a guide to the Committee in its efforts or for use in making comparisons with its results. The theoretical or analytical treatments which have been published, principally by European engineers, have most frequently been largely mathematical in character and without experimental verification or connection, and sometimes the assumptions on which the theory was based have been in error. Nevertheless, a number of engineers have made valuable tests on track, notably Dr. P. H. Dudley in this country, Cuenot in France, and Zimmermann and Ast in Germany and Austria, and these and others have contributed important discussions on several parts of the problem of the action of track. It is planned to give a bibliography of the literature of the action of track as a structure under load in a later report.* It is apparent then that railroad track has not been developed in the manner followed in the development and expansion of most engineering structures and structural parts where the scientific study of forces and stresses and the use of analysis and experiment have contributed in a marked way to improvements and growth. Instead, the present standards of track have been evolved from previous practice through a process involving extension and trial and judgment and experience. That track has attained its present state of excellence is a tribute to the sense, insight and judgment of the many men who have contributed to its growth and development. It is not surprising then that the Committee found it necessary to devote considerable effort to studying fundamental principles of the mechanics of track action, this being done principally through experimental work on track that may be described as ordinary track in good condition.

In the report the action of track as an elastic structure is first taken up. The part on conduct of tests, which is next in order, includes a description of the apparatus and the method of conducting tests, a statement of the preparation of test track and procedure of tests, and a discussion of reduction of data and accuracy of instruments. The results of tests are then presented and various topics related to the action of track are discussed. The information obtained on the action of the tie and on the transmission of pressure through ballast and roadway will be given in a succeeding report.

The Committee is continuing work on the subject assigned to it.

2. *Acknowledgment.*—The work of the Committee has been made possible through the contribution of funds by a number of corporations which have in this way expressed appreciation of the importance of the work and the need for information. Acknowledgment is made to the United States Steel Corporation, the Bethlehem Steel Company, the Lackawanna Steel Company and the Cambria Steel Company for their financial assistance. The American Society of Civil Engineers has also given support from its treasury.

Railroad companies have co-operated by furnishing facilities for the test work and thus have contributed largely to the success of the undertaking. The Illinois Central Railroad, A. S. Baldwin, Chief Engineer, gave the use of its tracks and of its locomotives and crews for the extensive set of tests made north of Champaign, Illinois, and credit is due this company for participating so largely in the provision for the tests. The Delaware, Lackawanna & Western Railroad, Geo. J. Ray, Chief Engineer, gave the use of tracks, locomotives and crews for the series of tests which were conducted near Dover, New Jersey. The Michigan Central Railroad provided the 100-lb. rails for the test track north of Champaign, and the Pennsylvania Railroad supplied the 125-lb. rails used.

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*A comprehensive list of the principal articles on this and related subjects up to 1909, presented by Dr. P. H. Dudley, may be found in Proceedings of the American Railway Engineering Association, Vol. 14, page 570 (1913).

Valuable assistance has been rendered by the University of Illinois. By a special arrangement, the Engineering Experiment Station has coöperated by giving the use of laboratory, shop, and office facilities and through the service of its staff. Mr. H. F. Moore, Professor of Engineering Materials, has devoted considerable time and energy to the design and development of instruments used in the tests and to the methods of testing. His special qualifications for this work have made his assistance most valuable. Credit should be given Dr. H. M. Westergaard, Instructor in Theoretical and Applied Mechanics, for his helpful work on the mathematical derivation of the equations given in the analysis of the action of track on a continuous elastic support.

To Mr. H. R. Thomas, who, as Assistant Engineer of Tests, has been in immediate charge of the testing operations and of the office work, acknowledgment is due not only for skill, industry and insight, but for the zealous spirit of scientific investigation with which the work has been conducted. Mr. R. R. Zipprodt has contributed to the accuracy of the work by his faithful and caretaking reading of records, calculation of results, and assistance in field work. Necessarily the personnel of the test party has been a changing one, but all those engaged in the work have exhibited care, loyalty and enthusiasm which has materially promoted the satisfactory progress of the investigation.

The Committee was fortunate in having the advantage of the experience of Dr. P. H. Dudley, a pioneer in testing railroad track. Mr. P. M. LaBach's familiarity with European literature relating to track and track tests has been of service. Since its formation the Committee has lost by resignation of membership Messrs. J. B. Berry and William McNab, whose duties in new positions prevented their giving further attention to the work of the Committee. A further loss in membership occurred through the death of Mr. Emil Gerber.

(II) THE ACTION OF TRACK AS AN ELASTIC STRUCTURE.

3. *The General Behavior of Track Under Load.*—A proper conception of the fundamentals underlying the action of track under load may be had only by considering the track as an elastic structure under load—the wheel loads are applied on the top of the rails; the rails act as flexible beams which rest upon flexible supports (ties); and the ballast and roadway upon which the ties rest are themselves yielding or flexible. The action of the various parts of this elastic structure affects the action of other parts. It is evident that the quality of flexibility and elasticity and stiffness of the supporting substructure constitutes an important element in track action and very greatly influences the action of the rail and affects the stresses developed in the various parts of the track.

Due to the stiffness of the rail and the yielding of its supports, the load from a wheel will be distributed over a number of ties. It is evident that the amount of yielding of the supports affects the values of the moments and stresses developed in the rail. As the distribution of the wheel load among a number of ties produces upward pressures or tie reactions of varying amounts, the determination of these tie reactions is connected with the problem of determining analytically the stresses in the rail. The properties of elasticity and stiffness in the rail, the tie, the ballast and the roadway enter in a complex manner into the development of the stresses in the track structure, the relative stiffness of the various parts affecting the results in any one part. The spacing of the wheels of locomotives and cars longitudinally along the track also influences the division of the load as pressures on the various ties, and hence influences the value of the stresses developed in rails, ties, and ballast. The track is flexible and its action under load is exceedingly complex, especially under the variable conditions found in tie bearings, ballast pressures, and roadway resistances.

Before attempting to give an analytical treatment of the moments and stresses developed in the parts of the track structure it may be well to discuss in a general way the action of the track structure. It is believed that this may be helpful in forming proper conceptions and in showing that certain notions of the manner in which the rail acts are incorrect and misleading.

A number of writers have obtained expressions for the bending moment and stresses in a rail by considering the rail as a simple beam supported on the two adjacent ties with the wheel load at a point half way between. This assumption gives a positive bending moment under the wheel of $\frac{1}{4}Pa$ where P is the wheel load and a is the distance center to center of ties. Other writers assume the beam to be fully restrained over the adjacent ties; this makes the positive moment $\frac{1}{8}Pa$ and the negative moment $\frac{1}{8}Pa$. Among other values which have been put forward are those of $0.18Pa$ for the positive bending moment under the load and $0.09Pa$ for the negative moment which is considered to be over the adjoining tie. In all of these it is virtually assumed that the load is taken only by the two ties adjacent to the load.

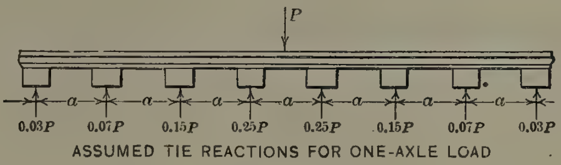
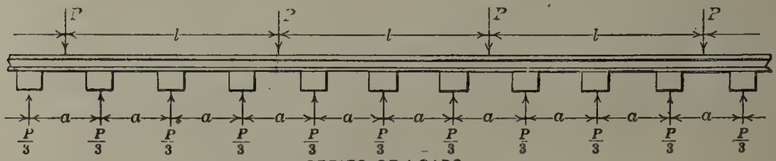


FIG. 1.

The conditions for a single wheel load may be approximated by taking the upward tie pressures as the loads on the rail and the wheel load as the reaction and in effect considering the rail cut at the last tie. The wheel load is distributed over a number of ties. The proportional part of the wheel load for each tie reaction depends upon the tie spacing, the stiffness of the tie and of the supporting substructure (ballast and roadbed) and the stiffness of the rail.

Consider that the tie reactions are somewhat as given in Fig 1, which approximate values found in tests. For this assumed distribution of tie reactions the bending moment under the load will then be $0.63Pa$ if we consider that the rail is not held down in such a way as to give negative reactions and negative resisting moments away from the wheel. It is seen from this illustration that a single load may give a high bending moment in the rail.

If, now, we consider a rail with an indefinitely large number of evenly spaced wheel loads, the tie spacing being, say, not more than one-third of the wheel spacing, it can be shown that for a given wheel spacing there is relatively little difference in the tie reactions until the wheel spacing becomes quite large. Assuming for present purposes that the tie reactions are equal, and that the wheels are at points midway between ties (Fig. 2), the positive bending moment under loads spaced three tie spaces apart is found to be about $0.263Pa$ and the negative bending moment $-0.154Pa$; and $0.345Pa$ and $-0.156Pa$, respectively, when the wheel spacing is four tie spaces. Expressing the bending moments in terms of the wheel spacing, l, the values become $0.088Pl$ and $-0.051Pl$ for $l = 3a$ and $0.086Pl$ and $-0.039Pl$ for $l = 4a$. It is readily seen from this that for the conditions assumed the bending moments and therefore the stresses in the rail will be dependent upon the wheel spacing and that this influence will continue until the wheel spacing becomes so great as to approach the conditions of single loads.



SERIES OF LOADS
WITH ASSUMPTION OF EQUAL TIE REACTIONS
FIG. 2.

The foregoing refers only to an indefinitely large number of wheel loads. For a small number the results will be greatly modified. In case two, three, or four wheels are spaced as above, it may be expected that the positive moment developed under the first and last load will be greater than the values given above, and the moment under intermediate wheels somewhat less than at the outer wheels. The amount of this difference will depend on the properties of the track including the stiffness of the rail. When there are other wheel loads, as truck wheels, not too far away, their effect is to modify the moments produced under the main wheels. On the whole the problem is very complicated.

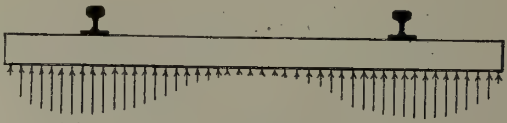
It is apparent that for conditions here considered changes in the closeness of tie spacing have relatively small effects on the bending moment developed in the rail by a given wheel loading; thus, for a wheel spacing equal to three tie spaces and an indefinitely large number of wheels so spaced the positive moment is about $.088\ Pl$, and if the ties were so closely spaced as to approach conditions of uniform distribution of bearing pressures from wheel to wheel, the positive bending moment would be approximately 0.083 *Pl.* It is also well to note that by this method of analysis the bending moment under the wheel may be expected to be nearly as much for wheels placed over ties as when the wheel is midway between ties. The foregoing discussion is based upon an assumption of uniform resistance of the substructure; i. e., that the stiffness of the elastic support is the same at each tie. It is evident that the stresses in the rail will be modified by the varying conditions of the tie, ballast, and roadway from point to point along the track.

Another important element in the problem of determining stresses in track is the effect of speed of locomotive and train. On this matter analysis alone can give little real information, and it must be expected that reliance must be placed upon experimental data.

The reaction of the tie or upward pressure of tie upon the rail depends upon the stiffness or the yieldability of the ballast and roadway, and also upon the stiffness of the rail which, of course, is dependent upon its moment of inertia. For good track and for a wheel spacing of not more than three or four tie spaces, the tie reactions for the ties between wheels will not vary greatly from each other. In front of the front wheel and behind the rear wheel of a set of wheels and also in front of and behind a single wheel the division of the reactions among various ties will be dependent upon the stiffness of track (rail, tie, ballast and roadway). The determination of this stiffness is one of the problems connected with the experimental work.

The distribution of the upward pressure of the ballast against a tie along its length may be expected to vary with the tamping and with the ballast and roadway conditions, and also depends upon the dimensions of the tie. For usual conditions of good track it would seem that the upward pressure will continue from the rail to the end of the tie and for at least a similar distance inside the rail. The exact distribution will depend upon the amount of bending of the tie and upon the permanent depression made in the ballast by the previous applications of load as well as upon the yieldability of the ballast and roadway. It will help in getting a conception of the action of the tie and ballast to consider the tie to be set on a bed of stiff springs; under load, the tie bends and the springs compress in proportion to the load put upon them. The stiffness of the springs depends upon the nature of the tie bearing and upon the consolidation of the ballast and other bearing material and their elastic properties. At the middle point of the tie the springs will generally have little bearing resistance. Fig. 3 gives a general notion of the distribution of the load along a tie. However, it must be expected that changes in the conditions of ballast and roadway, like freezing and thawing, differences in bearing conditions of adjacent ties, and the differences in resistance to repetition of pressure on the ballast along the length of the tie greatly modify the distribution, and such changes may be expected to increase the bending stresses in the tie.

It is usual to think of the distribution of pressure across the width of the tie as being nearly uniform; i. e., to consider the whole width of the tie as equally effective in transmitting pressure from the tie to the ballast. However, the ballast is composed of non-cohesive particles. As the transmission of pressure in directions other than the vertical is dependent upon friction between particles, the vertical pressures at the edge of the tie must be less than the pressures transmitted from the middle of its width, and this difference results in a distribution of pressure far from uniform across the width of the tie. For ties which are spaced not too far apart there is something of a reaction from the adjoining tie which may be expected to improve the distribution across the face. On the whole, however, the upward pressure against the tie cannot be uniform across its width.



A DISTRIBUTION OF PRESSURES ALONG A TIE

FIG. 3.

The ballast as a part of the structure of the track, in addition to other important purposes such as drainage, serves to transmit the tie pressures and reactions to the roadway, and acts to distribute the pressure more nearly evenly over the surface of the roadway. The laws governing the distribution and transmission of pressure through the ballast must be expected to have an important bearing upon the proportioning of the track structure. The formulation of these laws and the determination of constants relating to stiffness or yieldability, must await experimental work.

The roadway itself acting as a support also serves to transmit pressures and to distribute them to the surface of the earth below. The conditions of the roadway and the materials of which it is made may be expected to affect the action of the track. Little is known about this.

Enough has been said to show that the problem of the stresses in track is not a simple one, that it involves a large number of elements which have the nature of variables, that these variables enter into the problem in a complex manner, and that it is necessary to have a diversity of experimental data relating to the several variables before attempting to formulate the laws governing the stresses in track.

4. *Analysis of Track Action.*—An analytical treatment of the action of track under load has a value in the comparison of experimental data. It will be of use in establishing the physical properties of track. It should be an aid in forming proper conceptions of the manner in which track acts under load. It will be found to be a convenience in discussing the effect of rail section, tie spacing, driver and wheel spacing, depth of ballast and its stiffness, and condition of roadway. Such analyses are

based on the theory of flexure and involve complicated mathematical procedure. It may not be expected that an analysis of track action will fit accurately the many variables of track and, besides, the track varies in its properties from point to point. What is wanted is an analysis that may readily be used and that may easily be applied to combinations of wheel loads, to variations in wheel spacing, and to particular physical conditions of track. Most analytical treatments give results in such complicated form that the application is time-consuming. The simplified forms of analysis may not have a wide range of applicability. Various methods of analysis have been examined, including those given in foreign publications. A large amount of time and considerable effort have been devoted to a study of possible analyses, and a variety of methods of attack have been taken up. As a result, it is concluded that the method of analysis which is based upon the assumption of a continuous elastic support under the rail is by far the most convenient, most easily applied and most comprehensive in its application to the questions involved in the work of the Committee. This analysis lends itself very readily to a discussion of the general problems of track.

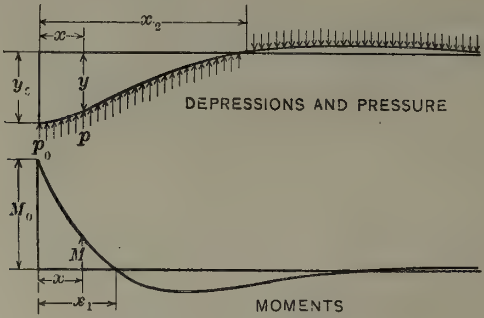
The assumption of a continuous support in place of tie supports is not an element of serious inaccuracy for the close tie spacing and large rail sections used on American railroads, especially as the use of values of track stiffness determined from data taken from tests on ordinary track carries into the constants established much of the condition of concentrated tie loads. The results of this analysis are similar in general character to those tried using concentrated tie loads. The method has been found to be more general and to have fewer limitations than the methods which are based upon concentrated tie loads.

The term, modulus of elasticity of rail-support, is introduced as a measure of the vertical stiffness of the rail-support. It may be defined as the pressure per unit of length of each rail required to depress the track one unit. It represents the stiffness and yieldability of tie, ballast and roadway, but does not involve the stiffness of the rail. As applied to ordinary track the load on one rail required to depress one tie one unit divided by the tie spacing will give the modulus of elasticity of rail-support. As an illustration consider that a series of wheel loads which depress the track an average of 0.3 in. gives a load equivalent to 10,000 lbs., per tie for each rail and that the tie spacing is 22 in.; the modulus of elasticity of rail-support is then 1500 lbs. per inch of length of rail per inch depression. The value of the modulus of elasticity of rail-support is so related to tie spacing and tie dimensions, depth of ballast, quality of tie, solidity of roadway, character of tamping and surface, and other conditions of the track and its maintenance that it will vary considerably according to the quality of the track.

The method of analysis will be developed, first for a single wheel load and then for a combination of wheel loads.

5. *Depressions, Upward Pressures, and Bending Moments in Rail for Track having a Continuous Elastic Support; Single Wheel Load.—*

Assume that the rail is supported continuously on an elastic support and that the support has a constant modulus of stiffness; i. e., that the depression of the track and the resulting upward pressures on the rail are directly proportional to each other. Assume further that the track construction is such that negative pressures may be developed. The following nomenclature will be used (see Fig. 4):



DISTRIBUTION OF DEPRESSION
AND BENDING MOMENT FOR SINGLE-WHEEL LOAD

FIG. 4.

$P =$ wheel load on rail at point which will be used as the origin of abscissas.

$E =$ modulus of elasticity of steel.

$I =$ moment of inertia of section of the rail.

$y =$ depression of rail at any point, x, it being assumed that there is no play or back-lash in the track. Downward displacement of rail is negative. However, in the applications to track the ordinary downward depressions of track will be spoken of as positive.

$y_0 =$ depression of rail at point of wheel load ($x = 0$).

$p =$ upward pressure against rail per unit of length of rail at any given point.

$p_0 =$ upward pressure against rail per unit of length of rail at the given wheel load ($x = 0$).

$u =$ an elastic constant which denotes the pressure per unit of length of each rail necessary to depress the track (rail, tie, ballast, and roadway) one unit. For the system of units ordinarily used it will be expressed in pounds per inch of length of rail required to depress the track one inch. u represents the stiffness of the track and involves conditions of tie, ballast, and roadway. It is termed the modulus of elasticity of rail-support.

$M =$ bending moment in rail at any point.

$M_0 =$ bending moment in rail at point of wheel load due to single wheel load ($x = 0$).

x_1 = distance from wheel load to point of zero bending moment in rail.

x_2 = distance from wheel load to point of zero upward pressure. It will be shown that x_2 is $3x_1$.

e = base of natural system of logarithms = 2.7183.

The fundamental condition on which the analysis is based is that the track depression at any point and the upward pressure on the rail per unit of length at the same point are directly proportional to each other. In other words, $p = uy$.

It will be recalled that in the mechanics of beams the derivatives of the elastic curve (first, second, third, and fourth) in their order represent or are proportional to (1) the slope of the elastic curve, (2) the bending moment in the beam, (3) the shear, and (4) the intensity of the load. In the case in hand, the fourth derivative (the intensity of load) has the unique relation of being directly proportional to the original function given by the equation of the elastic curve or curve of depression of track.

From the fundamental condition the differential equation of equilibrium* is

$$E\,I\,\frac{d^4 y}{d x^4} = \overset{P}{u\,y} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This differential equation is satisfied by the following equation:

$$y = -\frac{P}{\sqrt[4]{64\,E\,I\,u^3}}\,e^{-x\sqrt[4]{\frac{u}{4EI}}}\left(\cos\,x\sqrt[4]{\frac{u}{4\,E\,I}} + \sin\,x\sqrt[4]{\frac{u}{4\,EI}}\right) . (2)$$

The successive derivatives of this expression are:

$$\frac{d\,y}{d\,x} = \frac{2\,P}{\sqrt[4]{16\,E\,I\,u}}\,e^{-x\sqrt[4]{\frac{u}{4EI}}}\,\sin\,x\sqrt[4]{\frac{u}{4\,E\,I}} \ldots\ldots\ldots (3)$$

$$M = E\,I\,\frac{d^2 y}{d\,x^2} = P\sqrt[4]{\frac{E\,I}{64\,u}}\,e^{-x\sqrt[4]{\frac{u}{4EI}}}\left(\cos.\,x\sqrt[4]{\frac{u}{4\,E\,I}} - \sin\,x\sqrt[4]{\frac{u}{4\,E\,I}}\right) . (4)$$

$$E\,I\,\frac{d^3 y}{d\,x^3} = -\frac{P}{2}\,e^{-x\sqrt[4]{\frac{u}{4EI}}}\cos\,x\sqrt[4]{\frac{u}{4\,E\,I}} \ldots\ldots\ldots (5)$$

The equation for intensity of pressure against the rail is

$$p = -u\,y = P\sqrt[4]{\frac{u}{64\,E\,I}}\,e^{-x\sqrt[4]{\frac{u}{4EI}}}\left(\cos\,x\sqrt[4]{\frac{u}{4\,E\,I}} + \sin\,x\sqrt[4]{\frac{u}{4\,E\,I}}\right) . . (6)$$

The mathematical derivation of these equations will not be given, but the solution is seen to be correct because at the same time two types of conditions are satisfied:

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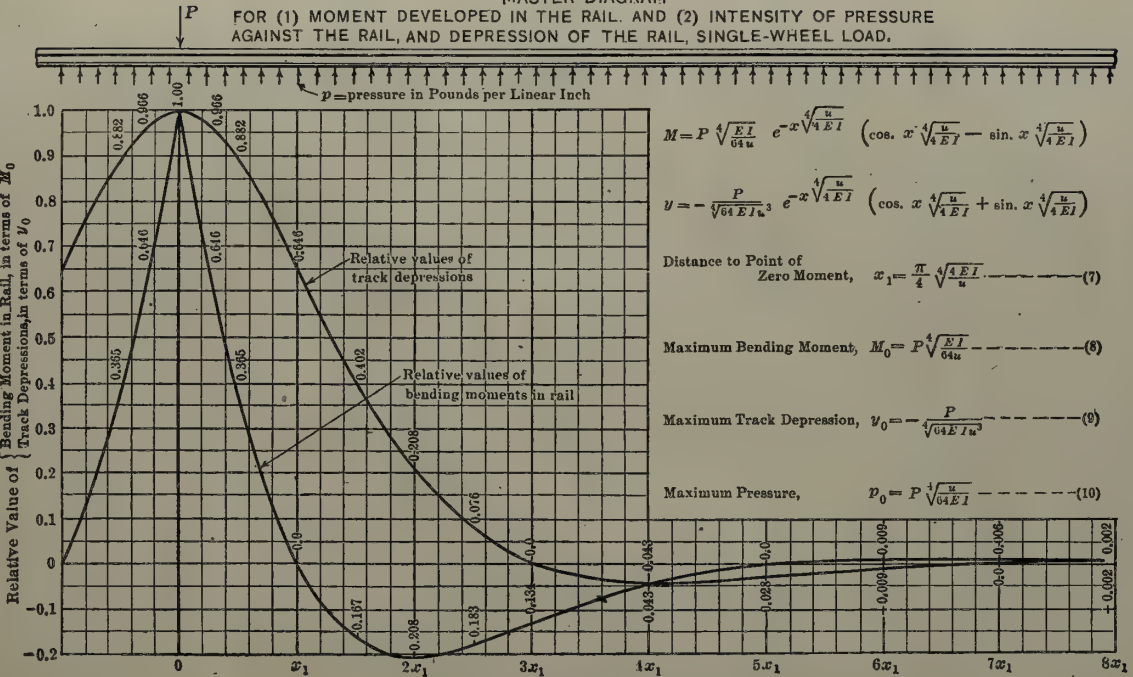
*The method of attack used in this mathematical solution may be found in Föppl's Technische Mechanik, Vol. III, pp. 254-268, edition of 1900, where a treatment of various problems concerning beams on continuous elastic supports is given. The method of analysis is here applied directly to the problem of the track and especially to the bending moment in the rail.

MASTER DIAGRAM
FOR (1) MOMENT DEVELOPED IN THE RAIL. AND (2) INTENSITY OF PRESSURE
AGAINST THE RAIL, AND DEPRESSION OF THE RAIL, SINGLE-WHEEL LOAD.



$$M = P\sqrt[4]{\frac{EI}{64u}}\; e^{-x\sqrt[4]{\frac{u}{4EI}}}\left(\text{cos. } x\sqrt[4]{\frac{u}{4EI}} - \text{sin. } x\sqrt[4]{\frac{u}{4EI}}\right)$$

$$y = -\frac{P}{\sqrt[4]{64EIu^3}}\; e^{-x\sqrt[4]{\frac{u}{4EI}}}\left(\text{cos. } x\sqrt[4]{\frac{u}{4EI}} + \text{sin. } x\sqrt[4]{\frac{u}{4EI}}\right)$$

Distance to Point of Zero Moment, $x_1 = \frac{\pi}{4}\sqrt[4]{\frac{4EI}{u}}$ ——— (7)

Maximum Bending Moment, $M_0 = P\sqrt[4]{\frac{EI}{64u}}$ ——— (8)

Maximum Track Depression, $y_0 = -\frac{P}{\sqrt[4]{64EIu^3}}$ ——— (9)

Maximum Pressure, $p_0 = P\sqrt[4]{\frac{u}{64EI}}$ ——— (10)

FIG. 5.

1.—The differential equation is satisfied by equation (2) for all positive values of x.

2.—All necessary conditions at special points are satisfied as follows:

(a). $E I \frac{d^3 y}{d x^3} = \frac{P}{2}$ for $x = 0$

(b). $\frac{d y}{d x} = 0$ for $x = 0$ and $x = \propto$

(c). $y = 0$ for $x = \propto$

The following special values of the functions will be useful:

The distance from the wheel load to the point of zero bending moment in the rail ($M = 0$ in equation (4)) is

$$x_1 = \frac{\pi}{4} \sqrt[4]{\frac{4 E I}{u}} \quad \text{.......................(7)}$$

The value of the maximum bending moment in the rail (which is at the wheel load) ($x = 0$ in equation (4)) is

$$M_0 = P \sqrt[4]{\frac{E I}{64 u}} = 0.318 P x_1 \quad \text{................(8)}$$

The value of the maximum track depression (which is at the wheel load) ($x = 0$ in equation (2)) is

$$y_0 = -\frac{P}{\sqrt[4]{64 E I u^3}} \quad \text{.......................(9)}$$

The value of the maximum intensity of upward pressure (which is at the wheel load) ($x = 0$ in equation (6)) is

$$p_0 = P \sqrt[4]{\frac{u}{64 E I}} = - u y_0 \quad \text{................(10)}$$

The distance from the wheel load to the point of zero upward pressure on the rail ($p = 0$ in equation (6)) is

$$x_2 = \frac{3 \pi}{4} \sqrt[4]{\frac{4 E I}{u}} = 3 x_1 \quad \text{..................(11)}$$

Fig. 5 gives master diagrams for (1) the moment developed in the rail and (2) the intensity of pressure against the rail and the depression of the rail, as determined from the foregoing equations. The diagrams represent relative values. The bending moment under the wheel load is given as unity and the values of the bending moment at other points (given as ordinates of the bending moment curve) are expressed in terms of the bending moment at the wheel load. The intensity of upward pressure (represented by the ordinate to the pressure curve) is also expressed in terms of the intensity of pressure at the wheel load as unity. Similarly, the abscissas of the two diagrams (bending moments and pressures) are expressed in terms of the distance from the wheel load to the point of zero bending moment as unity; i. e., as abscissa ratios. For any given track conditions the value of the maximum bending moment, M_0, may be computed by equation (8) and the distance x_1 to the point of zero bending moment by equation (7). To get the bending moment at any given point, find the ratio of x for the given point to x_1 and take the ordinate from the diagram by using this ratio as the abscissa. The bending moment in the rail at the given point will then be found by multiplying the value of the maximum moment, M_0, (already computed) by the ordinate found from the diagram. Similarly, the value of the intensity of pressure at a given point may be determined by multiplying the intensity of pressure under the wheel load by the ordinate for pressure at a given point obtained from the diagram.

As an illustration, consider a 100-lb. rail section ($I=44$) and that for the track conditions $u=1500$ lbs. per inch of length of rail per inch depression. x_1 is found to be 34 in. For a point at a distance of 66 in. from the wheel load the abscissa ratio is then $\frac{x}{x_1}=\frac{66}{34}=1.94$. From the master diagrams (Fig. 5), the bending moment ratio at the abscissa ratio 1.94, is -0.20; that is, the bending moment at 66 in. from the wheel load is 0.20 of that at the wheel load and is negative. By equation (8) the maximum moment, M_0, is $10.8P$. The bending moment at a point 66 in. from the wheel load is then the product of M_0 and -0.20, which is $-2.16P$. For the same point ($x=66$ in.) the relative value of the intensity of pressure is found from the diagram to be 0.22. By equation (10) the intensity of pressure at the wheel load, P_0, is $0.0115P$. The pressure 66 in. away is then the product of P_0 by 0.22, which is $0.0025P$.

It may be well to call attention to the effect of changes in the various properties of track upon the resulting track depressions and bending moments in rails as indicated by the several equations already given for a single wheel load. From equation (9) it is seen that y_0, the track depression under the wheel, varies directly as the magnitude of the wheel load P, and that it varies inversely as the fourth root of the moment of inertia of the rail section and inversely as the three-fourths power of the modulus of elasticity of rail-support. By this formula, doubling the moment of inertia of the rail section will result in a track depression under the wheel 84 per cent. as great as that for the lighter rail. Increasing the stiffness of the track support in such way as to double the modulus of elasticity of rail-support will result in a track depression 59 per cent. as great as that for the less stiff track. From equation (8) it is seen that M_0, the bending moment in the rail under the wheel, varies directly as the magnitude of the wheel load P, and that it varies directly as the fourth root of the moment of inertia of the rail section and inversely as the fourth root of the modulus of elasticity of rail-support. By this formula, doubling the moment of inertia of the rail section will result in a bending moment in the rail under the wheel 1.19 times as great as that for the lighter rail. Increasing the stiffness of the track support in such way as to double the modulus of elasticity of rail-support will result in a bending moment in the rail under the wheel 84 per cent. as great as that for the less stiff track. It should be noted that the foregoing applies to results for a single wheel load on a rail; the effect of two or more wheel loads is discussed in the following article.

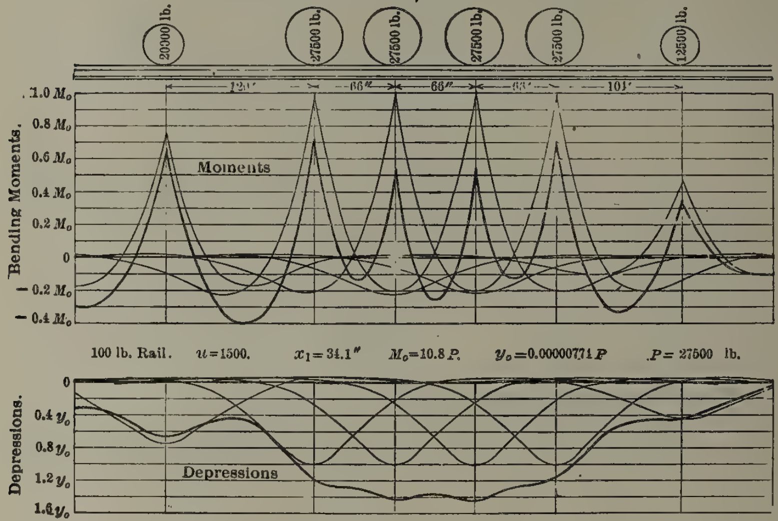
6. *Combination of Wheel Loads.*—To find the effect of a combination of wheel loads upon the track depressions and the pressures and the bending moment in the rail, as may occur with a given type of locomotive, the equations and diagrams for a single wheel load may be applied by the use of the principle of superposition; i. e., by considering that at a given point along the rail the combined effect of two or more wheel loads is the algebraic sum of the effects of the individual wheel loads. The effect which each wheel produces at any given point may be determined from the master diagram (Fig. 5), and the cumulative effect of the several loads may then be found by adding the components produced by each wheel load. This method of superposition of components is applicable to bending moments as well as to track depressions and pressures. The method may best be described through an illustrative example.

Take a Mikado locomotive with the wheel loads and wheel spacings given in Fig. 6 and let the problem be to calculate the bending moments in the rail at various points. In using Fig. 5 take as the abscissa the ratio, $\frac{x}{x_1}$, where x is the distance from the given point to the wheel load whose effect is to be determined and x_1 is the distance from the wheel to the point of zero bending moment in the case of a single wheel load. The bending moments will be obtained in terms of the maximum bending moment for a single wheel load (Equation (8).

To find the bending moment produced by a wheel load at a section in the rail x distant from the wheel load, take from the moment diagram in Fig. 5 the ordinate (which gives relative values of bending moments) corresponding to the given abscissa ratio $\frac{x}{x_1}$. The values may best be kept as relative values and considered as effects of the several wheel loads until the components have been summed. The bending moment at the given point may then be found by multiplying the maximum bending moment for a single wheel load (as found from equation (8)) by the ratio found by the summation of components. Where the wheel loads are unequal, use the ratio of the wheel loads in the calculations; thus, if the effect of the pilot truck wheel upon a point at the first driver is to be found use the ratio 12,500/27,500.

Consider that the track conditions are such that the modulus of elasticity of rail-support, u, is 1500 lbs. per inch length of rail per inch depression. Consider a 100-lb. rail section with $I = 44$. The value of the bending moment under a wheel load, where uninfluenced by other wheel loads, becomes for the constants of the track, from equation (8)

$M_0 = 10.8\,P$. From equation (7) $x_1 = 34$ in. For the distance from the first driver to the pilot truck wheel the abscissa ratio $\frac{x}{x_1}$ is $104/34 = 3.06$. For the distance from the first driver to the second driver the abscissa ratio $\frac{x}{x_1}$ is $66/34 = 1.94$. For the distance from the fourth driver to the trailer the abscissa ratio $\frac{x}{x_1}$ is $120/34 = 3.53$. Take ordinates from Fig. 5 for the several abscissa ratios. The effects of the several wheels are then found, and these components added algebraically.



BENDING MOMENTS AND TRACK DEPRESSIONS
FOR MIKADO LOCOMOTIVE, FROM ANALYSIS. 100-LB. RAIL

FIG. 6.

Bending Moment at First Driver:

Effect of first driver .... +1.00

Effect of pilot truck wheel, $(\frac{x}{x_1} = 3.06)$ .. $-0.13 \times \frac{12{,}500}{27{,}500}$ — .06

Effect of second driver, $(\frac{x}{x_1} = 1.94)$ .... — .20

Effect of third driver, $(\frac{x}{x_1} = 3.88)$ .... — .05

+ .69

The bending moment at the first driver is then 0.69 of that due to the weight of the first driver if it acted alone. The bending moment at this point becomes $M = .69\,M_0 = 7.45\,P = 205{,}000$ lb.-in.

Bending Moment at Second Driver:

Effect of second driver .... $+1.00$

Effect of first driver, $\left(\frac{x}{x_1} = 1.94\right)$ .... $-.20$

Effect of third driver, $\left(\frac{x}{x_1} = 1.94\right)$ .... $-.20$

Effect of fourth driver, $\left(\frac{x}{x_1} = 3.88\right)$ .... $-.05$

Effect of pilot truck wheel, $\left(\frac{x}{x_1} = 5.0\right)$ ....$-0.0 \times \frac{12,500}{27,500}$ $.00$

$+.55$

The bending moment at the second driver is then 0.55 of that due to the weight of the second driver if it acted alone. The moment at this point becomes $M = 0.55\, M_0 = 5.94\, P = 163,000$ lb.-in.

Bending Moment at Trailer:

Effect of trailer load .... $+1.00$

Effect of fourth driver, $\left(\frac{x}{x_1} = 3.53\right)$ ....$-.08 \times \frac{27,500}{20,000}$ $-.11$

Effect of first tender wheel, $\left(\frac{x}{x_1} = 4.0\right)$ ...$-.04 \times \frac{20,000}{20,000}$ $-.04$

$+.85$

The bending moment at the trailer is then 0.85 of that due to the trailer load if it acted alone. The bending moment is then $0.85\, M_0 = 9.18\, P =$ 184,000 lb-in.

The method may be applied in a similar way to the determination of the bending moments at points away from wheel loads. The values of the negative bending moments may thus be found. Fig. 6 shows in a general way the distribution of bending moments for the conditions assumed in the preceding illustration and for the locomotive shown. The light lines show the moment produced by the individual loads; the heavy line is the resultant moment due to the combination of wheel loads.

If the weights on the several drivers differ, as in the case with the Mikado locomotive of the Illinois Central Railroad used in the tests, the difference in the wheel loads may easily be taken into account in the calculations.

The track depressions caused by the assumed locomotive loading may be calculated by a similar process. At any point along the rail the components of track depressions caused by the individual wheel loads are found, and their algebraic sum gives the the track depression resulting from the combination of loads. The values may be taken from Fig. 5 (which gives track depressions in terms of y_0, the depression under a single wheel load) for any given value of $\frac{x}{x_1}$, where x is the distance from the given point on the rail to the wheel load whose effect upon the track depression is to be determined and x_1 is the distance from the wheel to the point of zero bending moment in the case of a single wheel load. The values of the ratios so found for the effect of the several loads may then be added algebraically; the product of this resultant ratio and y_0 is the resultant track depression due to the combination of loads. Fig. 6 illustrates the track depression for the Mikado locomotive used in the example illustrating the method of calculating bending moments. The light lines show the track depression produced by the individual wheel loads; the heavy line is the resultant track depression due to the combination of wheel loads. To illustrate the method of calculation, consider the case of the track depression under the first driver, as follows:

Effect of first driver	+1.00
Effect of pilot truck wheel, $(\frac{x}{x_1}=3.06)$ . . . $-.01 \times \frac{12,500}{27,500}$	$-.00$
Effect of second driver, $(\frac{x}{x_1}=1.94)$	+ .23
Effect of third driver, $(\frac{x}{x_1}=3.88)$	— .04
	+1.19

The track depression at the first driver is then 1.19 times that due to the weight of the first driver if it acted alone. Since y_0, the depression under the first driver acting alone from equation (9), would be $.00000774P = 0.213$ in. for the conditions already assumed for the track, the track depression at this point will be $1.19\ y_0 = 0.254$ in. The heavy line in Fig. 6 gives the resulting track depressions at all points along the locomotive. The vertical pressures may be found from the track depressions by the use of the modulus of elasticity of rail-support, u.

Figs. 7 and 8 give values of bending moment in rail and track depression for an Atlantic locomotive having the wheel loads and wheel spacing shown, the former for the worn 85-lb. rail section used on the test track and the latter for the 125-lb. rail section, the value of u being 1500 lbs. per in. per in.

Fig. 9 gives values of bending moment in rail and track depression for a single car having the loads shown, and Fig. 10 gives values for the truck wheels of two adjacent cars, the rail being the worn 85-lb. section of the test track on the Illinois Central Railroad and the value of u 1500 lbs. per in. per in.

It is seen that by the method here described the effect of a combination of two or more wheel loads upon the track depression and the bending moment in rail may be determined for the condition of continuous support here assumed. It is evident that a second wheel load placed within a limited distance from another wheel will cause a smaller bending moment to be produced in the rail at the wheel and likewise a larger track depression than would be produced with a single wheel load. The distance between wheels for which there will be a reduction

BENDING MOMENTS AND TRACK DEPRESSIONS FOR ATLANTIC LOCOMOTIVE, FROM ANALYSIS. 85-LB. RAIL

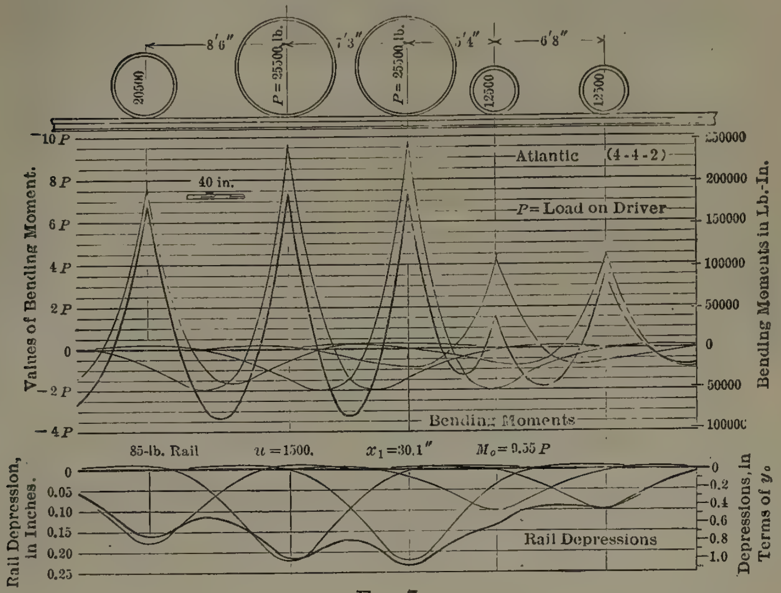


FIG. 7.

BENDING MOMENTS AND TRACK DEPRESSIONS FOR ATLANTIC LOCOMOTIVE, FROM ANALYSIS. 125-LB. RAIL

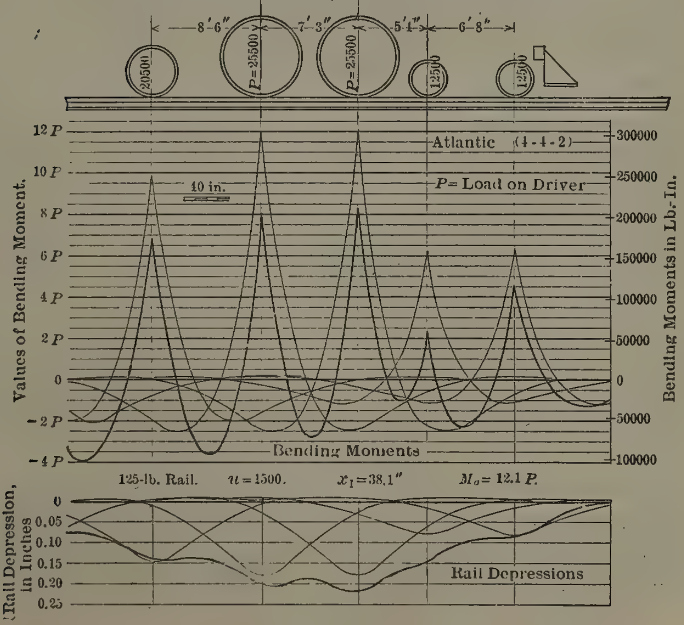


FIG. 8.

in bending moment at the first wheel will depend upon the rail section used and upon the modulus of elasticity of rail-support. A third wheel within this limiting distance (usually on the other side of the first wheel) will also act to decrease still further the bending moment in the rail at the first wheel. The effect of changes in the values of the moment of inertia of the rail section and of the modulus of elasticity of rail-support upon the magnitude of the bending moments and track

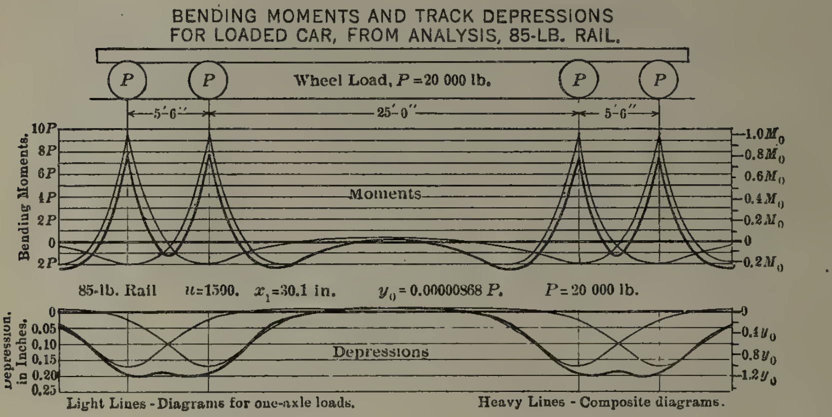


Fig. 9.

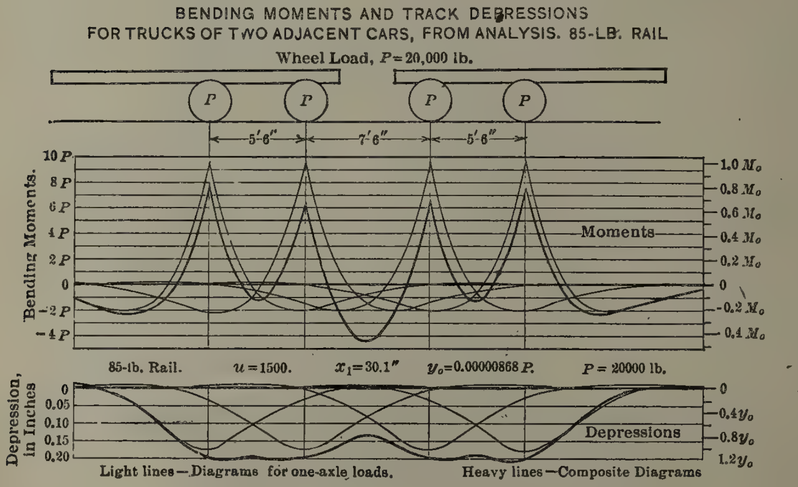


Fig. 10.

depressions will depend upon the spacing of the wheels. For any given wheel loading and spacing this effect may be readily determined.

7. *Discussion of Applicability of Analysis.*—From the foregoing illustrations it is seen that the method of applying the analysis is not complicated. The analysis is readily applied to determining the effect of a combination of wheel loads having any arrangement and any spacing. It takes into account the effect of the rail section used and of the stiffness of the track. Although the cross-ties form a discontinuous support, their width forms a considerable part of the rail length, and as the distance from a single wheel load to the point where the track depression is zero covers four to six tie spacings in such track as that on which the tests were made, the assumption of continuous support may not be expected to be generally much in error for the usual conditions of good track, especially as the method used for determining the value of the modulus of elasticity of rail-support will carry into this value some of the conditions attending the discontinuous support. Naturally the magnitude of the modulus of elasticity of rail-support will depend upon the size and spacing of the ties, the quality and depth of the ballast, the stiffness of the roadway, and the general condition of the track; and this property of track is one which must be determined by tests at different locations and under a considerable range of conditions.

It may appear at first thought that the assumption involved in the analysis that the rail support is capable of developing negative pressures may interfere with the accuracy of the results. Since there is play between the rail and the spikes, and since the ties cannot be expected to pull down on the rail, at least until there is some upward movement of the rail, there will be a region ahead of or behind a single wheel where little negative pressure may be developed in the track. However, in a combination of wheel loads with the spacing usually found in locomotives, the effect of adjacent wheel loads in the analysis is such that there will be no negative pressure except ahead of the pilot truck wheel, and here the weight of the rail itself will assist in developing the negative pressure. In the case of cars the analysis may give negative pressures at a point between the front truck and the rear truck of a car but not between that of one car and the next. It may be expected that the absence of resistance to the upward movement of the rail, as shown by a rail lifting from the tie, will tend to increase the bending moment in the rail at the first wheel over that given if the negative pressure were developed.

Perhaps a more serious element affecting the accuracy of this analysis, and of any analysis which could readily be applied to combinations of wheel loads, lies in the fact that at small loads the magnitude of the track depression may be greater accordingly than at large loads; in other words, that the modulus of elasticity of rail-support is not a constant—a condition which may exist when the track is in a poorly tamped condition. However, for the heavier wheel loads, like the drivers and trailer, this influence may not be very important. For a condition where the modulus of elasticity of rail-support is not a constant, the principle of superposition, which is utilized in most methods of analysis involving flexure of structures, is not applicable, and hence any treatment based upon the actual relation between pressure and depression will be altogether too complicated for any practical use.

It may not be expected that any method of analysis will give results that will fit accurately with experimental values. The variables of track are numerous and uncertain. Notwithstanding this, a usable analytical treatment is of great value in the comparison of experimental data and in acquiring a conception of the fundamentals of track action. It is believed that the analysis here given is acceptable from most points of view. Possibly in the future it may be found practicable to make empirical modifications of it which will fit more closely the data of tests.

(III) THE CONDUCT OF TESTS.

A. Apparatus and Method of Conducting Tests.

8. *General Requirements for Test Apparatus.*—An experimental study of stresses in railroad track involves the measurement of deformations or strains in rails, pressures existing at various points throughout the ballast, deflection of rails, depression and bending of ties, and depression at various points in the ballast and the roadway, when acted upon by a load. As the study of the effects of different kinds of loading, such as one-axle loading, two-axle loading, loading with locomotives of different wheel spacing applied both statically and at various speeds, was an essential part of the undertaking, it was necessary that the design of the instruments be made suitable for use under the diverse conditions of the various tests.

In the design of instruments, simplicity and reliability in operation rather than extreme sensitiveness were considered the prime requisites for measurements of strains, pressure, and depression. The instruments must be so designed that they will operate satisfactorily under variable weather conditions and give reliable results when used amid considerable dust and dirt. Some instruments are attached to rails subjected to severe vibration under rapidly moving locomotives; others are of necessity left buried in ballast for weeks at a time. As thousands of observations were taken and as the instruments had to be frequently adjusted or moved in the short time between the passage of trains on a busy track, the importance of simplicity and rapidity of operation can hardly be overemphasized. The dust and dirt unavoidably present would greatly lessen the reliability of instruments using complicated, delicate mechanism.

Nearly all the instruments used were designed specially for this work. To meet the severe conditions of field tests the instruments designed differ from the forms which might be suitable for instruments to be used under laboratory conditions. This difference is especially great for the instruments used under rapidly moving loads. In many respects the problems involved in the design of instruments were new, and in

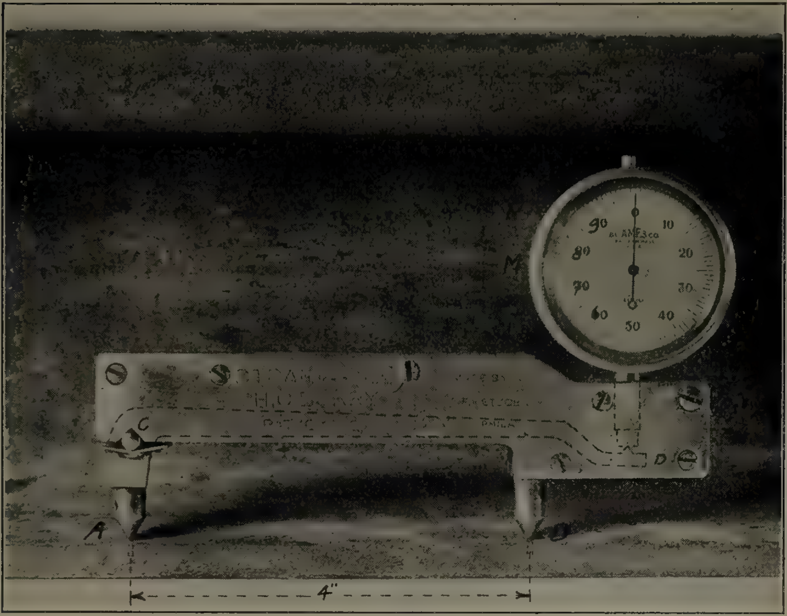


Fig. 11.—Berry Strain Gage.

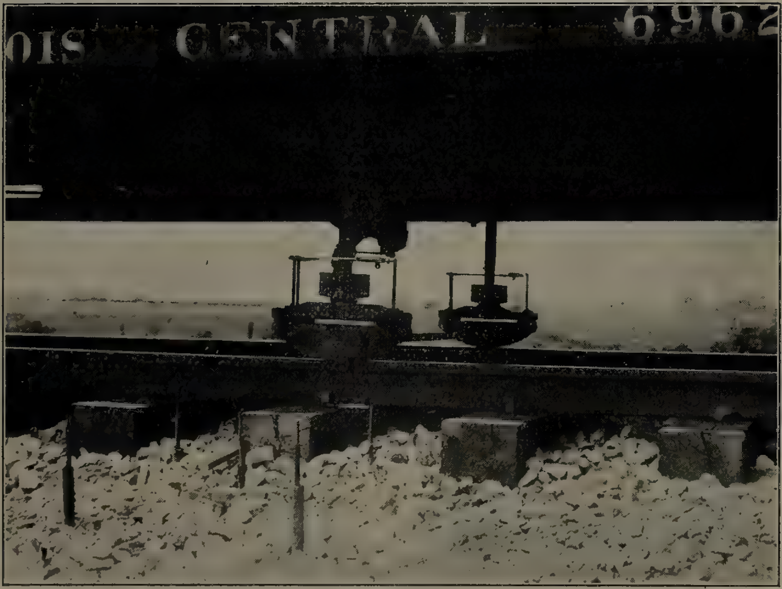


Fig. 12.—Load-Indicating Jacks in Position for One-Axle Load Test.

some cases many attempts were made and a number of forms of instruments were tried out before satisfactory results were obtained. Much time was spent in experimenting with various forms of instruments to meet the needs of existing conditions. Details have been changed from time to time as improvements were devised. The instruments described herein show the final form chosen after the various modifications of details. In all cases the instruments have given consistent results, have been found to be sufficiently sensitive to permit satisfactory interpretation of test results, have been accurate within the limits which were thought necessary and desirable, and have proved reliable and simple in operation.

9. *The Strain Gage and Its Use in Measuring Strain in Rails Under Static Load.*—In the tests with static loading longitudinal strains in the rails under bending load were measured by means of a Berry strain gage. Fig. 11 shows the strain gage used. The strain gage measures the change of distance between two small drilled holes *A* and *B*, called the gage points, which lie at the two ends of a gage line along which the strain is to be measured. To the frame of the strain gage are attached a dial micrometer and two pointed legs; one leg *B* is rigidly attached to the frame and the other leg pivoted to the frame. The pivoted leg forms one arm of a bent lever *A C D*, the other arm of which bears against the dial micrometer *M*, which is attached to the frame of the instrument. The pointed ends of the legs of the instrument are placed in the gage holes and the reading of the micrometer dial noted. This is done both with no load and with a given load. For any gage line the total strain is given by the difference between the reading under no load and the reading under load.* The general method of using the strain gage consists in taking readings on a series of gage lines with no load on the rail, and then taking a series of readings on the same gage lines with a known load on the rail. For accurate work the strain gage requires the touch and care of a skilled operator. The unit strain is found by dividing the total strain by the length of the gage line, and the longitudinal stress is determined by multiplying the unit strain by the modulus of elasticity of the steel, which for the purposes of these tests has been taken as 30,000,000 lbs. per sq. in. The length of the gage line used with the strain gage was four inches. The gage holes at the ends of each gage line were drilled about $\frac{1}{16}$-in. deep with a No. 54 drill (0.055 in. in diameter) and were located in the top of the base of the rail about ¼-in. from the edge. (See Fig. 11.)

10. *The Level Bar and Its Use in the Measurement of Rail Deflection and Tie Depression Under Static Load.*—For measuring the deflection of rail and the depression and bending of ties the level bar shown in

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*For a more detailed discussion of the strain gage and its use, see Bulletin 64 of the Engineering Experiment Station of the University of Illinois, "Tests of Reinforced Concrete Buildings under Load," by Talbot and Slater, and Proceedings of the American Society for Testing Materials for 1915, p. 1019, "Use of the Strain Gage in Testing Materials," by Slater and Moore.

Fig. 13 was used. It is a modification of an instrument used by Dr. P. H. Dudley,[6] Consulting Engineer of the New York Central Lines, for determining tie and rail depressions, differing from Dr. Dudley's instrument in the length of bar and in the micrometer device. The distance between the two conical points *A* and *B* is 20 in.

In use *A* is placed on a reference point, and *B* is placed on the spot whose deflection is desired. The leveling nut *N* is then turned, raising or lowering the plunger *P* until the horizontal bar stands level as shown by the position of the level bubble. The dial micrometer *M* is attached to the plunger *P*. A reading of the dial micrometer is taken without load and another with load. The difference between the two readings gives the change in elevation at one point with respect to the other. In cases for which a constant gage length of 20 in. was not convenient, instead of resting the instrument on *A* the longitudinal slot in the horizontal bar is placed on a projecting point, such as the pointed rod of a depression plug (*Q*, Fig. 28). The determination of deflection by the use of the level bar is not affected by the distance between reference points.

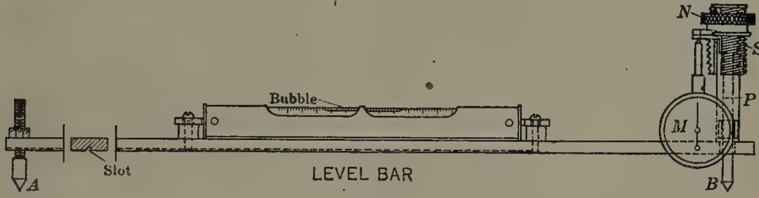


Fig. 13.

11. *The Depression Plug and Its Use in the Measurement of Depression in Ballast and Roadway.*—In order to measure the depression under static load of the ballast at various points and depths and also the depression of the roadway the device shown at the left in Fig. 14 was used. This device is called a depression plug. It consists of a plate *P* about 3 in. square, to which is attached a tube *T* with a rod *Q*, which is adjustable for height. The plate *P* is placed in the ballast or over the roadway where the depression is to be measured and outer tube *S* is placed over the tube *T*. Direct contact of *T* with the ballast would cause friction between them and consequently the depression of *P* would be affected. The enclosing of *T* with *S* prevents this. The lower end of the outer tube *S* is raised an inch or two above the plate *P*. As depression occurs at *P* the rod *Q* is depressed an equal amount and the depression may be measured by means of the level bar.

For measuring depressions directly under a tie the double depression plug shown at the right in Fig. 14 was used. The action of this plug is the same as that of the single depression plug. The average of the depression indicated by readings taken upon both rods of the double plug was taken as the average depression at the middle of the width of a tie.

12. *The Pressure Capsule and Its Use in the Measurement of Pressure in Ballast.*—For measuring the pressure transmitted to various parts of the ballast the pressure capsule shown in Fig. 15 was used. The elastic deflection of a thin steel diaphragm is used to measure the amount of pressure applied to the capsule. The pressure to be measured is received on the bearing plate *P*, which has an area of five square inches; the pressure is transmitted to the thin steel diaphragm *D*, which is fastened by screws around its circumference to the cast-iron case *B*. The screw *S* which fastens the plate *P* to the diaphragm *D* is hardened and bears on one knife edge of the small bell-crank lever *L* which is pivoted at *Q*. The vertical deflection of the center of the diaphragm is transmitted by the bell-crank lever (magnified about three times) in a horizontal direction to the rod *R* which slides in guides *N N′* and is enclosed in a horizontal tube *K* and finally bears against the plunger *T* of an indicating dial micrometer, whose movement is thus a measure of the elastic deflection of the diaphragm *D*. If the material of the diaphragm is not stressed beyond its elastic limit the deflection of the diaphragm, and the consequent movement of the pointer of the dial micrometer, may be used to measure the load on the plate *P*. Each pressure capsule was calibrated by placing it on a platform scale and by means of a screw clamp applying a series of loads covering the range of its use. The instrument was recalibrated after use. The dial of the micrometer was arranged so as to be adjusted to read zero at zero load.

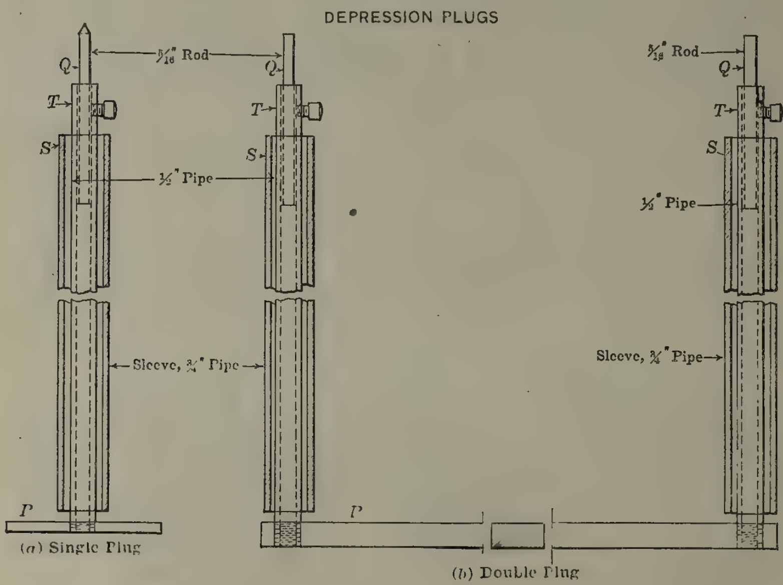


Fig. 14.

This does away with the need of applying a correction for zero reading.

The thin elastic diaphragm is made of hardened steel. The bearing plate serves to take load of any distribution or concentration upon it and to apply this load as a concentrated load at the center of the diaphragm.

This form of pressure capsule was adopted after trying various other devices. In one instrument tried a capsule was filled with water and the deflection of the cover measured by the amount of water forced into a small tube connected with the capsule. This instrument proved inaccurate under varying temperatures. In another form, the deflection of the cover of the capsule acted on the ends of a slightly bent spring, and the lateral motion of the spring was measured. This form was less sensitive than the form shown in Fig. 15. Attempts were made to measure pressures by means of the varying electrical conductivity produced in various substances by variations in pressure. This method did not give satisfactory results.

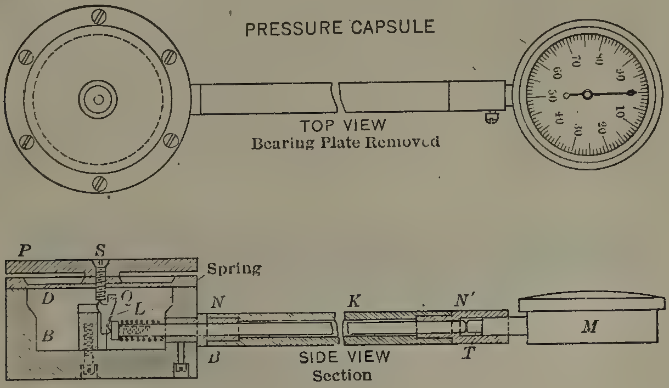


Fig. 15.

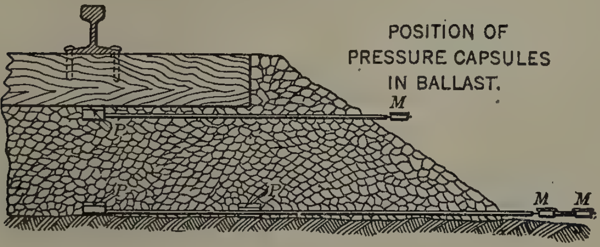
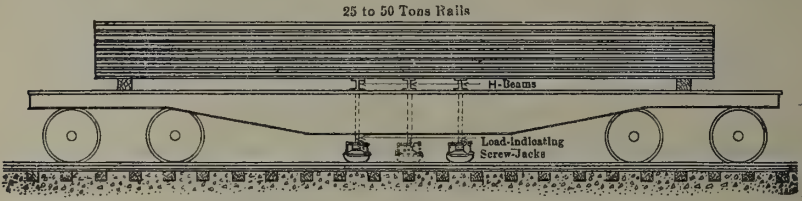


Fig. 16.

The position of pressure capsules as placed in the ballast is shown in Fig. 16. At the spot where it is desired to measure pressure a capsule is placed with the surface of the bearing plate *P* perpendicular to the direction of the pressure to be measured. Above the bearing plate is spread a cushion of fine material to guard against undue concentration of pressure from large pieces of ballast. The horizontal tube *K* with its enclosed rod extends outside the ballast and at its end carries the dial micrometer *M*. The total pressure carried by the bearing plate *P*, when load is applied to the track, is indicated by the reading of the micrometer dial, and the intensity of pressure for that spot in the ballast is found by dividing the total load on the pressure capsule by the area of the bearing plate *P*. Sand and dirt are prevented from coming between the bearing plate *P* and the diaphragm of the instrument by friction tape wrapped round the case of the pressure capsule.

13. *Indicating Jacks and Their Use in Applying One-axle and Two-axle Loads.*—For applying loads equivalent to a one-axle load and to a two-axle load a flat car loaded with 25 to 50 tons of rails was used in connection with special load-indicating screw jacks. As shown in Fig. 17, the rails on the car were supported on H-beams placed crosswise of the car. Against the bottom of these H-beams the upper ends of the indicating screw jacks bore. The lower ends of the screw jacks bore against the rails through curved bearing blocks having a radius approximating that of an ordinary car wheel, but not coned. The outer jacks in Fig. 17 indicate the position for two-axle loading and the middle one for one-axle loading.



LOADING APPARATUS FOR ONE-AXLE AND TWO-AXLE LOADS.

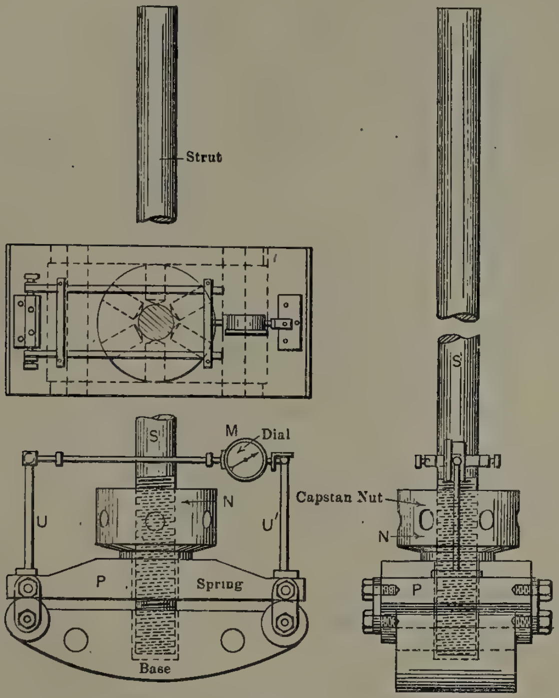
FIG. 17.

The construction of the load-indicating screw jacks is shown in detail in Fig. 18. The load is applied by turning the capstan nut *N* on the screw *S*, and the amount of load is measured by means of the inclination given to the ends of the flat nickel-steel spring *P*. As this spring deflects under load the ends are inclined and with them the uprights *U U′*. The distance between the tops of the uprights is lessened, and the amount of motion is indicated by the dial micrometer *M*. The load-indicating screw jacks were calibrated in the laboratory by loading with known loads in a testing machine. Stresses and depressions were generally measured for one rail only, but in order to have both rails symmetrically loaded it was necessary to use load-indicating jacks on both rails. Fig. 12, from a photograph, shows the jacks in place under the car of rails ready to apply a one-axle load.

14. *The Stremmatograph and Its Use in Measuring Rail Strains.*—In order to measure the strains in rails under moving locomotive loads

it is necessary to use recording instruments, as the motion of an indicating pointer would be too rapid to be followed accurately by the eye. Recording instruments for track tests under rapidly moving loads must withstand severe vibration, must be used in places exposed to dust and dirt, and must permit a large number of readings to be taken. It is evident that some simple form of recording device is essential, one with few parts, one which may be quickly attached in position, one whose record may be read quickly and accurately.

A number of types of recording instruments were considered before deciding on the type to be used. Instruments with multiplying levers were regarded as unsuitable; experience with recording instruments has shown that uncertain effects are introduced by inertia of moving parts if the load is rapidly applied. Instruments involving the use of a ray of light reflected from a mirror to a sensitized photographic film were considered. This type of instrument gives the highest degree of sensitiveness of any type considered, but its use involves rather cumbersome arrangements of light-proof tubes leading from the mirror to the film, a special source of light would be necessary, and much time would be



DETAILS OF LOAD-INDICATING JACK

FIG. 18.

required to develop films. A very ingenious mirror-type extensometer was designed and constructed by Mr. W. M. Dawley and this instrument may be of great service in case very delicate measurements of strains are found to be necessary in the development of further tests. In general, however, for track tests the use of mirror-type instruments with photographic records would consume too much time, and they would be too likely to get out of adjustment under field conditions.

For general use in measuring rail strains it was decided to use an instrument involving the general principle utilized in the stremmatograph developed by Dr. P. H. Dudley, Consulting Engineer of the New York Central Lines. In that instrument*, as designed by Dr. Dudley, a sharp steel point draws a diagram on a flat plate of polished phosphor bronze. No mechanical multiplying device is used, and the motion of the recording point across the bronze plate (ordinates of the diagram) is equal to the strain in the rail between gage points. The gage points were on the under side of the base of the rail, near the outer edge; measurements were not made along the inner edge. The bronze plate is given rectilinear motion at right angles to the motion of the recording point by a screw drive. The record graven on the bronze plate is examined under a high-power microscope and the strain at any desired point on the record, given by the height of the diagram, is measured by means of a filar micrometer eye piece.

The instrument used by the Committee differs in several important details from the stremmatograph described above. When the record is made on a bronze plate, the scribing needle must be reground after taking a few records. This regrinding was a slow process, requiring a high degree of skill. After experimenting with various means of making a record, it was decided to make the records of strain on a glass disc very lightly smoked. It was found that a steel needle sweeps a smooth-edged, sharply-defined path through the very fine particles of lampblack which coat the disc, and that the width of such a path is very uniform.

After experimenting with various kinds of needles, it was found that a steel phonograph needle was suitable for making stremmatograph records on smoked glass, and such needles were inexpensive and could be readily obtained. Phonograph needles as purchased were found to be too hard and brittle, and before being used to trace stremmatograph records the temper was drawn slightly by heating in oil at a temperature of 536 degrees Fahrenheit (280 degrees Centigrade) for thirty seconds and then quenching in water.

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*The following articles by Dr. P. H. Dudley give some results of tests made with his stremmatograph:

Stresses in Rails under Moving Loads, Railroad Gazette, May 20, 1898.

Stresses in Railway Track under Moving Trains, Engineering News, Oct. 6, 1898.

Stresses in Rails under Moving Loads, Railroad Gazette, Oct 21, 1898.

Rail Stresses—Tests of Unit Fiber Strains, Engineering News, Nov. 14, 1901.

Stremmatograph Tests, etc., Bulletin International Railway Congress, June, 1904.

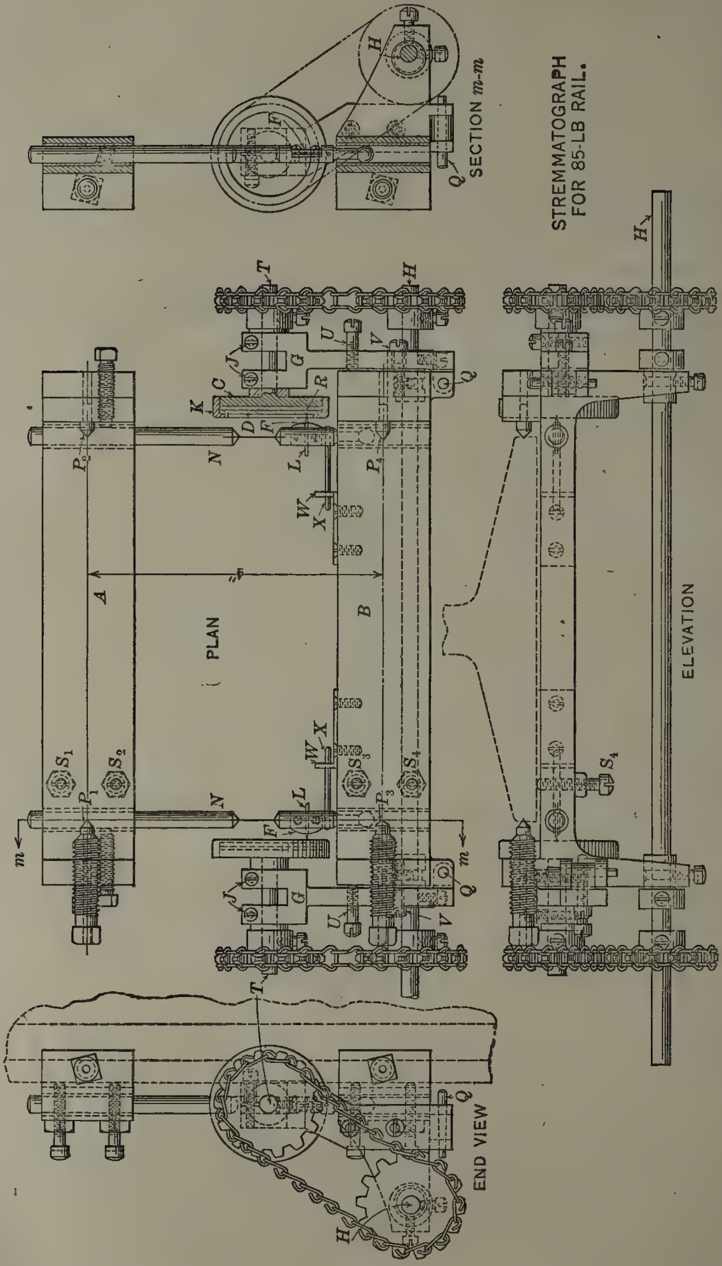
For moving the glass disc to give length to the record, a rotary motion of the disc was used instead of the rectilinear motion used by Dr. Dudley, and a circular diagram drawn rather than a straight-line diagram. Freedom from play in bearings is of the very highest importance for securing accuracy in such an instrument. Bearings for circular motion can be made free from perceptible play more easily than can bearings for straight-line motion. The plane of the record disc is vertical. The most serious vibration of the rail is up and down vibration, and this vibration has the least dulling effect on the needles and causes the least variation in the width of the line if the plane of the record disc is vertical.

For smoking the glass discs used in the stremmatograph and other recording instruments, gasoline was used. Of all of the various coatings tried, it was found that the smoke from burning gasoline gave a coating on which the needle scratches left the sharpest clear-cut lines. In smoking the discs, these were held by a special device and passed back and forth through the smoke. The gasoline was burned in a small open cup holding about two ounces.

As the tests progressed various details of the stremmatograph were altered. The latest form of the stremmatograph used is shown in Fig. 19. Two clamps, *A* and *B*, are attached to the base of the rail 4 inches apart, and between these two clamps extend two needle bars, *N N*. One end of each needle bar is in the shape of a spherical head with a slender stem; the other end of each needle bar is clamped by a set-screw to the clamp, *A* (called the anchor clamp); and the spherical end of each needle bar is free to slide in a brass sleeve in the clamp *B* (which is called the record clamp). Any point on the needle bar will move with respect to any point on the record clamp *B*, an amount equal to the stretch or the shortening of the rail along the line of the needle bar. With the instrument shown, records are obtained for strains along both the inner and the outer edges of the base of the rail.

In the first design, measurements of strain were made on only one side of the rail, but when it was found that there was an appreciable difference in the stresses on the two sides of the rail the design was altered so as to include measurements on the two sides of the rail.

Each of the clamps *A* and *B* is fastened to the base of the rail by one set screw and one fixed hardened steel point. The clamps are prevented from pivoting or rotating about the clamping points by the steadying screws S_1, S_2, S_3 and S_4 which bear against the bottom of the rail. The brass sleeves in the clamps are so located that the center lines of the needle bars come directly under the inner and outer edges of the base of the rail. The fit of the sliding end of a needle bar in its guide sleeve must be made with care. Each needle bar is fitted with a brass clamp plate *F*, which holds a hardened phonograph needle *L*, which bears against the smoked-glass record disc *D*. It is necessary that the needle bars shall be rigid in a vertical plane, and that they shall have consider-

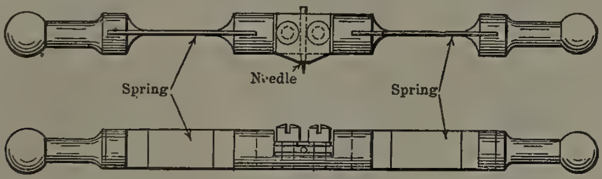


STREMMATOGRAPH FOR 85-LB RAIL.

FIG. 19.

able "spring" in a horizontal plane so that an even pressure of the needle point against the record disc may be maintained. This combination is effected by making a part of each needle bar a thin flat spring with the width vertical. To prevent turning, the sliding end of each needle bar is held by a pin *X*, which slides in a guide slot *W*.

In the development of the stremmatograph various types of needle bars were tried. First a needle bar without any spring was tried, but this did not give satisfactory records. Next the type shown in Fig. 20 was used. This type was fitted with two springs and gave better records than the stiff bar, but at high speeds this type of bar "chattered" and caused the needle to cut into the glass record disc. It was found out later that this type of bar had an appreciable "lag" due to excessive flexibility in a horizontal plane; the result of this is that the results obtained are somewhat small. Practically all of the records of 1915 were obtained with instruments fitted with this second type of needle bar. The change to the later type of needle bar accounts for the improvement in consistency of results of 1916 tests over the results of 1915 tests. The 1916 tests and all subsequent tests were made with instruments fitted with the form of needle bar shown in Fig. 19.



EARLY TYPE OF NEEDLE-BAR FOR STREMMATOGRAPH

Fig. 20.

Each of the smoked-glass record discs, on which the records of strain are taken, is clamped against a face plate *C* by means of a screw cap *K* (Fig. 19). Between the record disc and the face plate is placed a circular piece of sheet rubber *R*. Each face plate is driven by a shaft *T*, which rotates in double bearings *G* and is itself driven by sprocket and chain from a drive shaft *H* located below the instrument. This drive shaft *H* turns in eccentric bearings which permit adjustment of chain tension, and is driven through a flexible spring coupling (shown at *A*, Fig. 21) by a long shaft which extends to one side of the track.

It is of highest importance that all play be taken up in the bearings of the driven shaft *T*, as any radial play is recorded as strain on the smoked-glass disc. The double bearings *G* were ground to fit the shaft *T*, and the split bearings were fitted with tightening screws *J* for taking up wear. In order to eliminate all play, the bearings were tightened on the shaft so that the shaft drove with considerable friction. Washers and collars were used to prevent axial play.

For convenience in changing discs or needles the bearings *G* for the disc shaft *T* were attached to the clamp *B* by means of a taper pin *Q*,

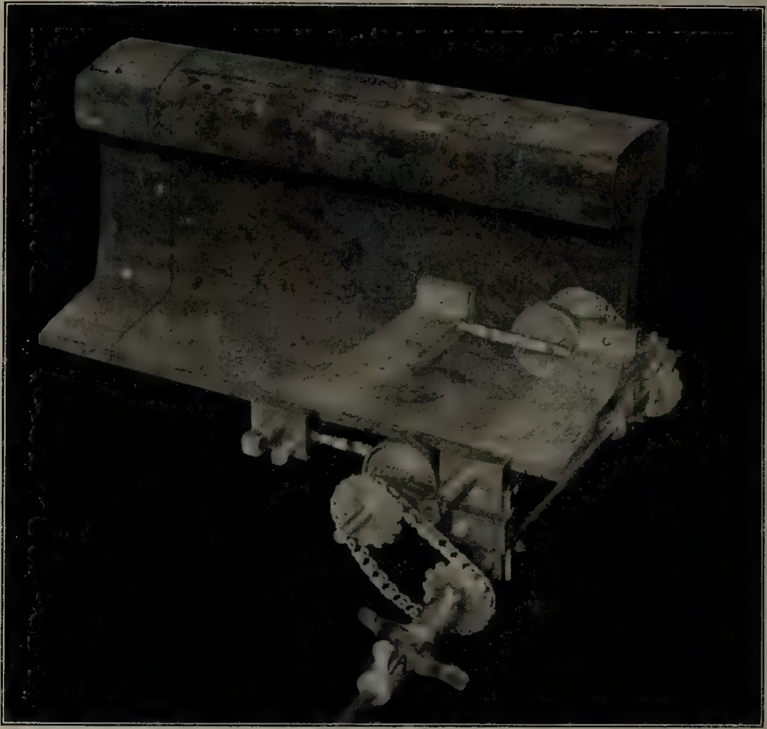


Fig. 21.—Stremmatograph in Position on Rail.

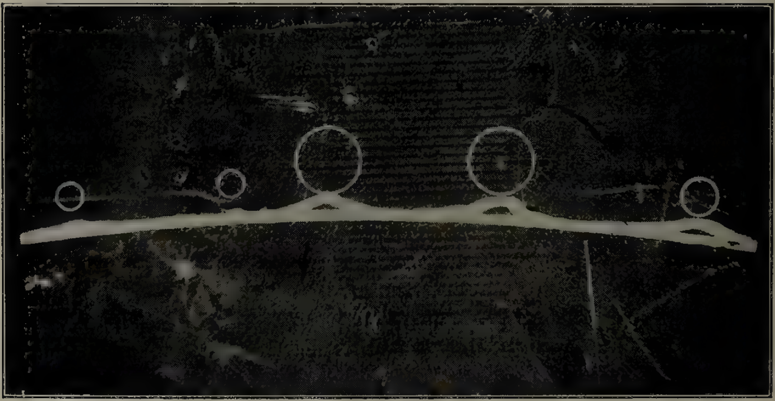


Fig. 22.—Photomicrograph of Stremmatograph Record.

which served as a pivot around which the bearings, disc shaft, face plate, and disc could be swung so that the screw cap *K* could be unscrewed, the smoked-glass disc removed and another substituted or so that the needle could be changed or adjusted. When in position for taking records the bearings, shaft and disc were clamped fast by clamp screws *U* and *V*.

Fig. 21 is from a photograph of a stremmatograph in position on a rail. That part of the instrument behind the rail is shown by means of a double exposure of the photographic plate used in taking the picture. Fig. 22 is from photomicrographs of typical stremmatograph records. The zero line was obtained by giving the record disc one complete revolution with no load on the track. Height of strain diagram is measured from this zero line.

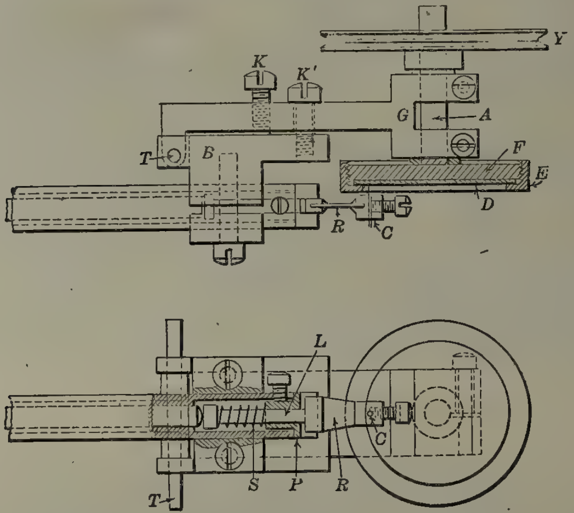
As the records of strain were obtained for both edges of the base of the rail, it was necessary to make the clamps to fit the particular size of rail upon which the stremmatograph was to be used. Except for the clamps, the details of the instruments are the same for all sizes of rail.

Instruments were made covering the following rail sections: 56-lb., 75-lb., 85-lb. and 100-lb. A.S.C.E. rail sections; the 125-lb. P. R. R. rail section and the 136-lb. L. V. R. R. rail section. Fig. 19 shows the instrument used for the 85-lb. A.S.C.E. rail. Usually for any test four instruments were used at one time.

15. *The Recording Pressure Capsule.*—For recording pressures under moving load at various points in the ballast recording pressure capsules were used. These differed from the pressure capsules used for static tests only in the substitution of recording devices for the dial micrometers used with the pressure capsules for static loads, which are shown in Fig. 15. Fig. 23 shows the recording device for the instrument for tests with moving loads. In the end of the horizontal tube which extends sidewise from the pressure capsule is fastened a bearing plug *P*, in which slides a plunger *L*, which is normally held in its innermost position by a spring *S*. At the outer end of the plunger *L* is fastened a flat spring *R* with its width vertical, and at the outer end of this flat spring is a needle chuck *C*, in which a needle is held by a set screw.

A block *B* is clamped on the outer end of the horizontal pipe extending from the pressure capsule. To this block is fastened by means of a taper pin *T*, and clamping screws *K*, K^1, a double bearing *G*, in which turns a shaft *A* to which is attached a face plate *F*, on which a smoked-glass disc *D* is clamped by the screw cap *E*. The bearing, the face plate, the disc and the screw cap are the same as the corresponding pieces used with the stremmatograph. For the recording pressure capsule the disc shaft *A* is driven by a round belt operating the grooved pulley *Y*. The deflection of the diaphragm of the pressure capsule causes a motion of the plunger *L*, which, in turn, causes motion of the needle. The motion of the needle draws the diagram as the smoked-glass disc D is turned and the moving load passes the instrument. The radial ordinates of this diagram measured from a base circle for zero load are proportional to the amount of deflection of the diaphragm of the pressure capsule and hence are a measure of the pressures at the point in the ballast where the capsule is located. The measurement of the radial ordinates of pressure capsule records is made with a microscope fitted with a micrometer eyepiece.

When the pressure capsule was being designed little attempt was made to work out the details of an instrument which would operate satisfactorily under moving loads, as only static load tests were being made at that time. Later the recording device was designed for use with the pressure capsules under moving loads and a number of tests were run. It is thought, however, that due to the inertia of parts in the instruments, measurements of pressures under moving loads at speed will be inaccurate and unreliable, especially at high speeds.



RECORDING DEVICE FOR PRESSURE CAPSULE

Fig. 23.

16. *Drive Rig for Moving Load Tests.*—The drive apparatus for turning the discs of the recording instruments in the moving load tests is shown at one side of the track in Fig. 25. The main drive shaft is driven by hand through a crank and worm reducing gear, and this in turn drives small shafts which are connected with the several stremmatographs. While the attempt was made to have the speed of rotation of the drive about proportional to the speed of the locomotive, this was not considered a very important matter. As long as the drive was fast enough to separate the portions of the curve corresponding to the passage of successive wheels, no trouble was encountered in reading the

various strains from the curves, nor was it necessary to have a means for establishing the position of the locomotive with respect to the location of the instrument other than that given by the records themselves. As can be seen from Fig. 22 the records show definite maximum values in the curves corresponding to the passage over the instruments of various wheels of a locomotive. It is obvious that such a maximum value can only occur when a wheel is over the instrument, so it is unnecessary to have other means for determining the position of the locomotive.

17. *Measurement of Deflection of Rail by Means of a Camera.*—In moving load tests, the deflection of various points of the rail was measured by means of a double exposure photograph. At intervals there were glued along the outside of the rail small pieces of black paper with small white crosses on them. A Speed Graphic camera for 5 in. x 7 in. plates was set up at a distance of about 10 ft. from the rail, as shown in Fig. 25. At this distance the vibration of the camera was found to be small, and it did not materially affect the results of the measurement except at high speeds. The camera was fitted with an anastigmat lens having a speed of F 4.5 and a focal plane shutter giving a minimum length of exposure of 0.001 second. For any given observation a photograph was made of the unloaded rail with its attached white crosses. Then, without changing the plate in the camera or moving the camera, the camera shutter was set for the next exposure. The camera shutter was fitted with an electro-magnet release and the wires from the magnet led through a battery to a contact piece attached to the rail. As the locomotive ran on the test section of track the front truck as it passed over the contact piece closed the circuit through the electro-magnet, and a second photograph of the rail with its attached white crosses was made on the plate in the camera. On the plate when developed, each small white cross shows as a vertical line crossed by two horizontal lines, and the distance between the horizontal lines is proportional to the depression of the rail. This distance was measured by means of a microscope with a micrometer eyepiece and multiplication by a factor gave the amount of the rail depression.

With one camera the depression of rail may be measured for a length of about ten feet. Generally two cameras were used at one time both operated at the same time by the magnetic release. In examining the developed photographic plates with a microscope the maximum magnification used was about 75 times. Under higher magnification the silver grains on the sensitized surface of the plate showed as small particles to such an extent that the edges of the lines whose distance apart was to be measured were blurred. With the camera 10 ft. from the track and a magnification of 75 in the measuring microscope, the deflection of rail can be determined with a precision of about 0.01 in.

For this photographic measurement Cramer Crown single coated photographic plates were used. These plates were found to combine high sensitiveness to light with fine grain of silver. Fig. 24 is from a print of a double exposed plate for depression measurement.

18. *Measurement of Speed of Locomotive.*—For measuring the speed of the locomotive as it passed the test section of track an automobile speedometer of the revolving magnet type was used. The speedometer was driven through a flexible shaft by a leather-faced friction wheel which ran on the tread of a wheel of the locomotive, generally the trailer. The speedometer was placed so that its dial was visible to the engineman and to an observer stationed in the cab. The accuracy of the speedometer was checked at various speeds by noting its reading while the locomotive was run at various uniform rates of speed over a stretch of track, the time being measured by a stop watch. The friction drive wheel of the speedometer was pivoted so that it could be swung back out of contact with the wheel when the locomotive was run backward. When in operating position the friction drive wheel was held against the wheel by a spring.

19. *Manufacture of Instruments.*—The strain gage, the camera for recording depression of track, microscopes for reading records from recording instruments, and the speedometer were purchased. The load-indicating jacks and the depression plugs were made by local firms from designs furnished. All other instruments were made in the shop of the Laboratory of Applied Mechanics of the University of Illinois by the mechanician employed on the test work. In all there were manufactured 14 stremmatographs, 2 level bars, 73 pressure capsules, and various special appliances and connecting parts for apparatus. It should be stated that after the instruments had been first made, it was necessary for the mechanician to spend a considerable amount of time in maintaining the instruments and in making such modifications as were found to promise better results.

B. PREPARATION OF TEST TRACK AND PROCEDURE OF TESTS.

20. *Test Sections on Illinois Central Railroad.*—The track of the Illinois Central Railroad used in the test work is on the double track main line about two miles north of Champaign, Illinois. At this location all freight trains are diverted from the main line tracks and run through the yards over special freight tracks, and only passenger trains are run over the main line tracks. For test purposes, these tracks are therefore comparatively free from traffic disturbances.

The stretch of track used is on an embankment 4 to 8 ft. high composed of loam and clay. A single-track road was built in 1854 and the second track was added in 1900. Age has given compactness to the embankment and it was in dry condition throughout the tests.

The ballast at this place consists of crushed limestone; it usually has an average depth under the ties of about 12 in. The rails in this stretch of track are A.S.C.E. section 85 lbs. per yard. The rails on the

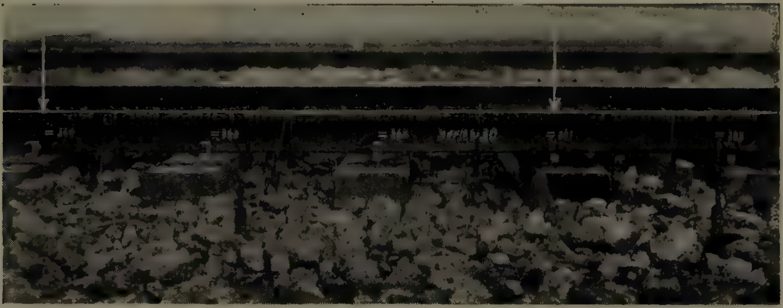


FIG. 24.—DOUBLE-EXPOSURE PHOTOGRAPH, AS USED IN MEASURING TRACK DEPRESSION.

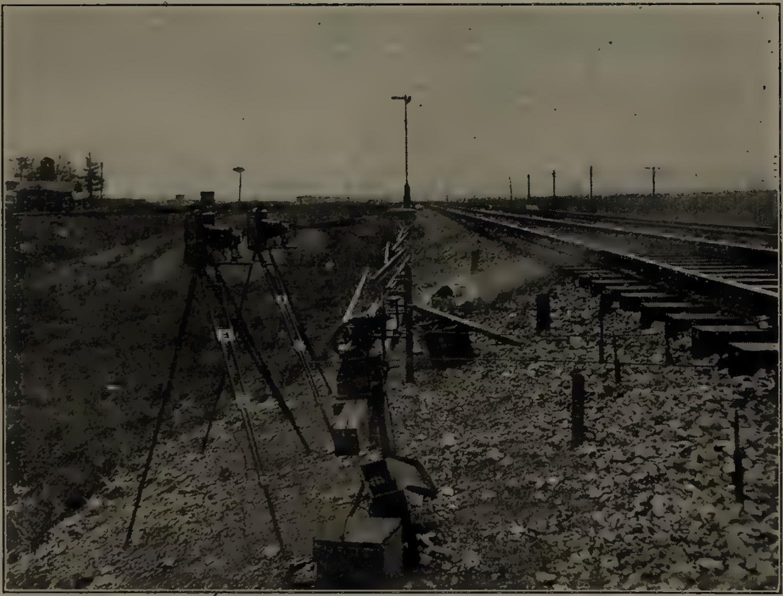
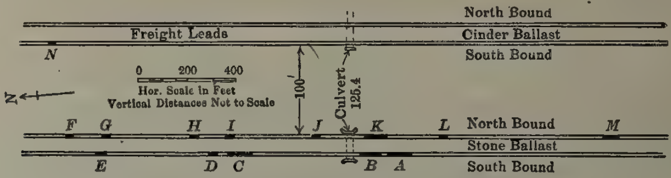


FIG. 25.—TEST SECTION ON ILLINOIS CENTRAL RAILROAD.

southbound track are 33 ft. long and were laid in 1902; those on the northbound track are 30 ft. long and were laid in 1900.

To provide uniform known conditions of track for the tests, four stretches were specially prepared. For these test sections special oak ties replaced the original ties. Four such sections were prepared within a short distance of each other. On one section the ballast had a depth of 6 in. below the ties; on another 24 in., and on two others 12 in. On one of the last-named sections the ties were 7 in. x 9 in. x 8 ft.; on all others they were 6 in. x 8 in. x 8 ft. In locating the test sections, depths of ballast closely approximating the desired depths were found, and the track was raised to make the proper depth. The special ties had been prepared accurately to size and were of uniform quality. When first prepared these special test sections were laid with the 85-lb. rail which originally had been in the track. Later, when it was desired to use heavier rails in the tests the 85-lb. rails were removed and replaced by the heavier rails, whose sections are shown in Fig. 107. The sections used were chosen because they were readily available and give considerable range in weight. The relative location of the various test sections is shown in Fig. 26. The size of rails used is given in Table 1. The 100-lb. rails were placed on section K, which has 24 in. of ballast and 6 in. x 8 in. x 8 ft. ties. The 125-lb. rails were placed on sections B and K, which have 12 in. and 24 in. of ballast, respectively, and 6 in. x 8 in. x 8 ft. ties.



RELATIVE LOCATION OF TEST SECTIONS
ON ILLINOIS CENTRAL RAILROAD

FIG. 26.

In order to check up the results of the tests on these special test sections and also to find out what stresses may be expected under some other conditions of the track, tests were also run on adjacent sections of track which had not been specially prepared. The ties here are mostly oak, but replacements are being made with creosoted pine ties with tie plates. The relation of the location of these sections to the special test sections will be seen in Fig. 26. Sections D and J were chosen as being representative track in ordinarily good condition and having the usual ties and tie spacing. Sections E, F, G, I and L were chosen as showing the results of a decayed or badly cut tie. Section M was at a low spot in the track. Sections D, E, F and G were used for static tests with the loading apparatus, and sections D, J, I, L and M were used for tests with moving loads. Section H, having tie plates, was used for static tests. Section N on the freight lead having the ordinary run of ties and cinder ballast was used for tests with moving loads. All this track was laid with 85-lb. rail. The depths of ballast were as indicated in Table 1.

21. *Preparation of the Test Sections.*—In placing the special ties used for the special test sections, the old ties were removed and the new ones put in without disturbing the ballast below the bottoms of the ties. This work was done by the regular section men of the Illinois Central Railroad. For each test section, the depth of ballast was determined by excavating to subgrade near the ends of the ties on each side of the track at two points in each rail length. The track was raised sufficiently to give the required depth of ballast under the ties. In no case was it necessary to raise the track more than 2 in. in order to secure the desired depth of ballast.

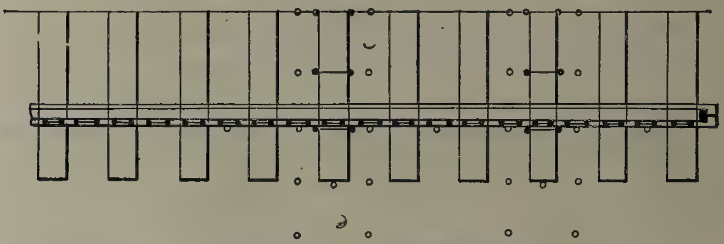
At the north rail length of each test section, the ties were spaced 22 in. apart, center to center. The purpose of this spacing was to get three tie spaces for a 66 in. wheel spacing. Under the other two rail lengths of each section the ties were placed as nearly as possible according to the standard practice of the Illinois Central, which uses 18 ties to a 30-ft. rail and 20 ties to a 33-ft. rail (approximately 20-in. spacing). The placing of these ties was done with considerable accuracy, the position that each was to occupy being marked on the rail for the guidance of the section men.

TABLE 1—DESCRIPTION OF TEST SECTIONS ON ILLINOIS CENTRAL RAILROAD.

Section.	Rail.	Ties.	Ballast.	Remarks.
A	85 lb.	Sp'l. 7 by 9 in. by 8 ft. 0 in.	12-in. stone.	Special section.
B	85 and 125-lb.	Sp'l. 6 by 8 in. by 8 ft. 0 in.	12-in. "	do.
C	85-lb.	Sp'l. 6 by 8 in. by 8 ft. 0 in.	6 in. "	do.
D	do.	About 6 by 8 in. by 8 ft. 0 in.	About 6-in. stone.	Ordinary track.
E	do.	do.	do.	Decayed tie.
F	do.	do.	do.	do.
G	do.	do.	do.	do.
H	do.	do.	do.	Tie-plates used.
I	do.	do.	do.	Decayed tie.
J	do.	do.	About 24-in. stone.	Ordinary track.
K	85, 100 and 125-lb.	Sp'l. 6 by 8 in. by 8 ft. 0 in.	24-in. stone.	Special section.
L	85 lb.	About 6 by 8 in. by 8 ft. 0 in.	About 15-in. stone.	Decayed tie.
M	do.	do.	" 8-in. "	do.
N	do.	do.	" 6-in. cinder.	Freight lead.

Whenever the track had been in use long enough to need it, it was tamped and put in good surface. After such resurfacing tests were not run until sufficient time had elapsed for traffic to compact the ballast that was disturbed; generally ten days or two weeks was allowed.

In preparing the special test sections the depression plugs were put in place after the special ties had been placed and the track raised to its proper level. In putting in these plugs, both between ties and under ties, the tie was removed and the ballast excavated down to the level of the subgrade. The depression plugs were then placed in the positions shown in Fig. 27 and 28 and the ballast replaced. As this material was replaced it was carefully tamped. In placing certain of the single depression plugs in the 24-in. ballast, a slightly different method was used. A piece of 6-in. pipe was driven with a sledge until its lower end was at the bottom of the ballast. The ballast inside of the pipe was excavated, the depression plug put in place, and the ballast then replaced and thoroughly tamped as added. The pipe was then pulled up and used in placing the next depression plug. After the depression plugs had been in place a few days, the track was again thoroughly tamped. The track was retamped as often as the spot became low until the tests were started While it was realized that this method of placing the depression plugs was open to the objection that it disturbed the ballast, there was no way of placing them without doing this. As no tests were made until the depression plugs had been in place about two weeks, it is thought that the ballast was fairly well compacted by that time.


LOCATION OF DEPRESSION PLUGS

o Single Depression Plug **●—● Double Depression Plug**

●—● Strain Gauge Line

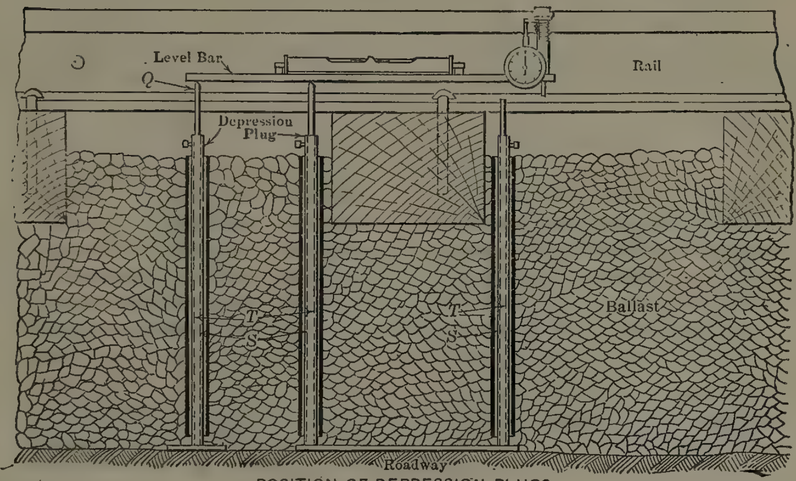
FIG. 27.

After the depression plugs were in place the rods (*Q*, Fig. 304a were put in and adjusted for height so that the level bar could be used from the rail to the adjacent plugs, and from these plugs to the others In Fig. 18 the projecting upper ends of the tubes and rods of several depression plugs can be seen.

22. *Preparation of Test Track for Level Bar Measurements.*—T furnish a fixed reference point from which measurements of depression could be made, a reference stake R was driven 80 in. from the rail whose deflection was to be measured (Fig. 29). A reference bar consisting of a piece of 2 in. x 4 in. lumber was fastened at one end with a pivoting joint by a clamp to the rail, the other end resting on a knife-edge bearing on the reference stake. Level bar measurements were made from the reference stake to the rail, readings being taken between screws in the top of the reference bar, the outer screw being directly over the knife edge. From the point on the rail readings were taken along the rail and from the rail to the various depression plugs. As shown in

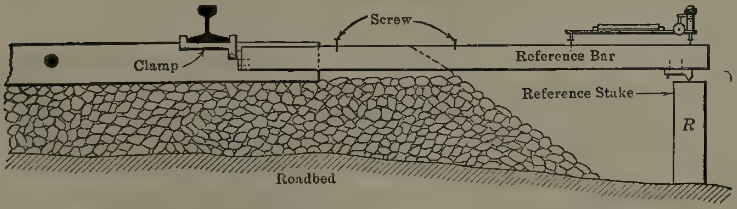
Fig. 29, readings were taken from the reference stake to the rail and then along the rail. Additional reference stakes were located at sufficiently close intervals to furnish check on the depression readings.

23. *Preparation for Strain Gage Measurements.*—For static tests preparations were made for strain gage measurement of longitudinal strains in the rail by drilling gage holes at the ends of the gage line along which strain was to be measured. These gage holes were on the top of the base of the rail about one-fourth of an inch from the edge of the rail and in the early tests on only one side of the rail. These gage lines were placed over every tie and between ties for the three rail lengths of each test section. Fig. 27 shows the typical arrangement of gage lines for a test section of track.



POSITION OF DEPRESSION PLUGS

FIG. 28.



ARRANGEMENT OF APPARATUS FOR MEASURING TRACK DEPRESSION

FIG. 29.

It was found that the change in temperature of the rail (while in the shade when the load was in place) was sufficient to affect the strain gage measurements appreciably. In order to determine the corrections to be applied for this variation, readings were taken on a gage line located on a short unstressed piece of rail kept under the same conditions as the rail upon which readings were being taken. In this way it was possible to make correction for temperature.

24. *Procedure of Tests—Static Load Tests.*—For making a static load test of track the test party generally consisted of six men, there being three observers and three recorders. One man operated the strain gage, one handled the level bar along the rail and another handled the level bar on the depression plugs. Each of these observers had his own recorder.

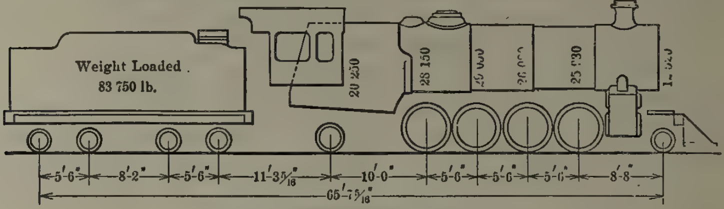
The typical procedure of the static load tests when the loading apparatus for one-axle and two-axle load was used, was as follows: The car loaded with rails was taken to the test section and carefully "spotted" so that the H-beams (Fig. 17) came directly over the points where the load was to be applied. The brakes of the car were then set and the engine uncoupled and run away from the test section far enough not to affect the results. After the load-indicating jacks had been put in place ready to apply the load, zero-load readings were taken with the strain gage and the level bars. Load was then applied by means of the jacks and a set of load readings taken. The next load increment was applied and the load readings taken. After the desired number of increments of load had been applied (usually four) the load was removed and the zero-load readings again taken. Readings on the standard gage lines were taken at the beginning and end of each set of load and zero-load readings. To take a complete set of readings, including two sets of zero readings and four load readings, required from an hour and a half to two hours. For the one-axle load there were a total of about 80 strain gage readings, 115 level bar readings along the rail, and 90 level bar readings on the depression plugs. For the two-axle load there were about 115 strain gage readings, 115 level bar readings along the rail and 125 level bar readings on the depression plugs.

The typical procedure in static load tests with a locomotive was practically the same as when the loading apparatus was used. Zero-load readings were taken with all instruments. The locomotive was then run on the test section and spotted at the desired point. Load readings were taken and then the locomotive was spotted at a new position and load readings taken. After taking load readings with the locomotive at the number of points desired the locomotive was run off the test section and zero-load readings again taken. As it took about an hour to take a set of readings under the full length of the locomotive and tender, it was thought best to check up on the zero-load readings at frequent intervals in order that errors introduced into strain gage results by the variations of temperature might be corrected for. Hence when readings were taken under the full length of the locomotive, generally only one set of load readings was taken between the two sets of zero-load readings. Each set of readings under the full length of the locomotive and tender included about 120 strain gage readings, 60 level bar readings to the rail and 30 level bar readings to the depression plugs. Since many of these depression plugs were under the locomotive, the 30 readings on these required about as long as the 60 readings on the rail.

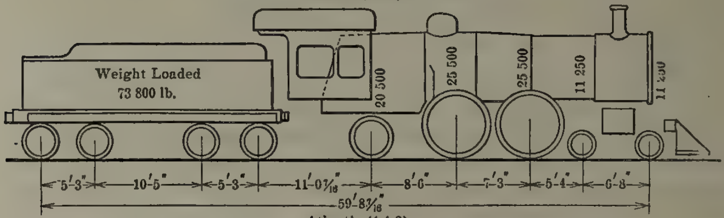
25. *Procedure in Measuring Static Pressure in Ballast.*—The measurement of the pressures in the ballast by means of the pressure capsule generally was not made at the same time as the other tests. In measuring these pressures, the dial micrometers were placed in the ends of all of the tubes of the pressure capsules and the dials set to read zero. Load was applied at the desired point either by means of the loading apparatus or the locomotive, and the dials were then read. As soon as the desired loads or load in the desired position had been applied and the readings taken, the load was removed and the zero-load readings checked to see if they returned to zero. These readings under load were reduced to unit pressures expressed in pounds per sq. in., as described later.

26. *Procedure of Tests; Moving Load Tests.*—Tests in which the load on the test track was produced by a locomotive running over the section are designated as moving load tests. On the tests on the Illinois Central Railroad, three types of locomotives were used in moving load tests, a Mikado locomotive (2—8—2), an Atlantic locomotive (4—4—2), and a Pacific locomotive (4—6—2). Fig. 30 gives diagrams of the locomotives used, with their wheel loads. The same types of locomotives were used on static load tests as on moving load tests, except that the switching locomotive was used only on static load tests and the Pacific locomotive was used only on moving load tests. In all tests with the Atlantic type of locomotive, the same locomotive was used. The Pacific locomotive used in the 1916 tests was not the same as that used in the 1915 tests. In tests with the Mikado type of locomotive, use was made of whatever Mikado locomotive was available, and in the course of the work tests were made with 25 Mikado locomotives. In all cases except the one where the equalizer was found blocked up, the locomotives were in good working condition. The tires were in good condition, there being in no case evidence of much wear. The Mikado locomotives were used at speeds up to 35 miles per hour, that being the maximum speed permitted by the regulations of the Illinois Central Railroad. The Atlantic and Pacific locomotives were used at speeds up to 60 miles per hour, a few tests being made at speeds higher than 60 miles per hour. The distance available for acquiring speed made it difficult to attain speeds higher than 60 miles per hour.

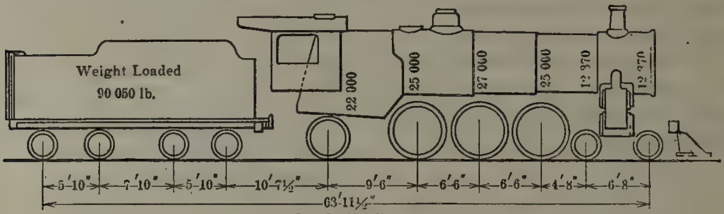
In all moving load tests (except at very low speeds) steam was shut off as the locomotive approached the test section of the track. It was found that the tractive effort of the locomotive produced an appreciable effect on the rail stresses, which was somewhat variable, and it was decided to eliminate this variable at first and to study only the effect of speed, leaving the effect of traction effort for investigation later. In order to have the counterweight of the locomotive drivers in the same position in all tests, before beginning a test the drivers were slipped to cause the counterweight to come to a definite position for a given position of locomotive on the test section. A few tests were made with the counterweight in different positions to see something of the effect of change of position of counterweight. As the engineman was cautioned to start slowly and not to use the brakes severely, little trouble was experienced from the position of the counterweight changing during the tests.



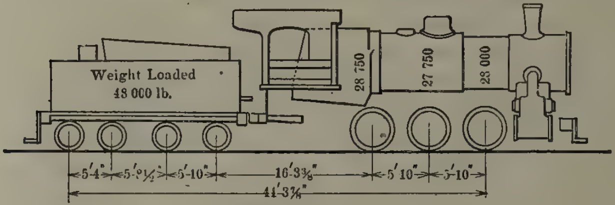
Mikado (2-8-2)



Atlantic (4-4-2)



Pacific (4-6-2)



Switching (0-6-0)

DIAGRAMS OF
FOUR TYPES OF ILLINOIS CENTRAL LOCOMOTIVES.
FIG. 30.

For moving load tests the test party usually consisted of three men. The procedure of a typical moving load test was as follows: The stremmatographs were attached to the rails, and the recording devices attached to the pressure capsule tubes, the drive shaft rigging set up and connected to the stremmatographs and to the recording pressure capsules. The speedometer was attached to the locomotive and, in case it was desired to measure rail deflection, the cameras for measuring deflection were set up and the electrical connections for tripping the camera shutters made. Smoked-glass discs were then put in place on the stremmatographs and on the recording pressure capsules; the pressure of the discs against the recording needles was adjusted, and a zero-load line drawn on the discs by rotating the drive shaft. The locomotive was then run over the test section at the lowest speed used (5 miles per hour) and records obtained by turning the drive shaft by the handwheel. Then the locomotive was run over the test section at next to the highest speed used (25 miles per hour for the Mikado, and 50 miles per hour for the Atlantic and Pacific locomotives). A run was then made at next to the lowest speed (15 miles per hour for the Mikado and 35 miles per hour for the Atlantic and Pacific locomotives), and last a run was made at the highest speed (35 miles per hour for the Mikado, and 60 miles per hour for the Atlantic and Pacific locomotives). While this order and these speeds were not always followed, they are typical. The records for the runs at four speeds were obtained on the same glass discs. After the runs at four speeds, the smoked-glass discs were removed and examined under a microscope for evidence of error in adjustment of instruments or of dullness of recording needles. Any dull needles were replaced, necessary adjustments made, new smoked-glass discs were put in place, and another series of runs was made. After at least three good sets of records had been obtained for each instrument at a given location of the instruments, the stremmatographs were moved to a new location.

In setting up the apparatus for moving load tests, two men usually worked at attaching the four stremmatographs to the rail while the third man set up the drive apparatus and attached the speedometer to the locomotive. During the runs, one man rode on the locomotive in order to read the speedometer and to note any variations in handling or operation of the locomotive. The two other men turned the drive shaft as the locomotive passed the section and noted the position of the counterweight as the locomotive backed over the test section for the next run. As soon as the runs at four speeds had been made, the two men removed and examined the records and replaced smoked discs for the next run.

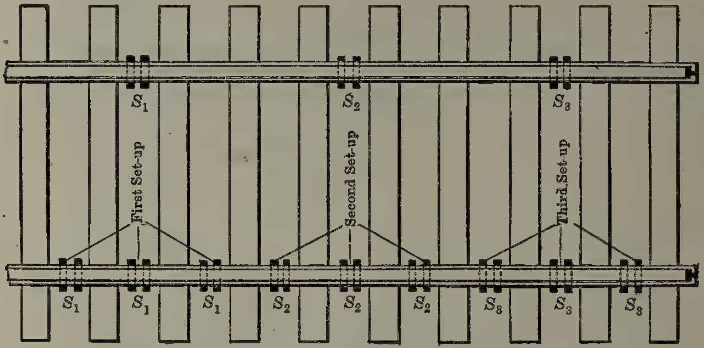
27. *Preparation for Moving Load Tests.*—Fig. 25 shows the arrangement of apparatus as set up for the moving load tests, and Fig. 31 is a diagram of the usual arrangement of stremmatographs. Four stremmatographs were used at one time, three on one rail between adjacent ties and one on the other rail opposite the middle instrument of the three. At each test section the instruments set up successively at three adjacent locations covering a distance of eight tie spaces near the center.

of the rail length. Strain measurements were made along the middle of the rail rather than near the ends because the effect of rail joints would be appreciable near the ends, and this effect was regarded as a special problem to be studied later.

Under favorable conditions, after skill had been acquired, the required number of records for a given weight of rail and one condition of track and for one type of locomotive were obtained in from a day and a half to two days.

28. *Tests on Delaware, Lackawanna & Western Railroad.*—Tests were made on the tracks of the Delaware, Lackawanna & Western Railroad at a point near Dover, N. J., during the fall of 1916.

The section of track chosen for the tests was on the eastbound main line of the Delaware, Lackawanna & Western Railroad about one mile east of the station at Dover, N. J. The tracks here are laid with 101-lb. D., L. & W. R. R. rail section on 7 in. x 9 in. x 8 ft. 6 in. creosoted pine ties, tie plates being used on every tie and screw spikes throughout. The ballast consists of trap rock having a depth of about 18 in. under the ties. Directly beneath the ballast there are two feet of cinders, which were originally used as ballast. Beneath the cinders is a light embankment of clay mixed with boulders. For purposes of the test the original rail at this point was replaced by new 105-lb. D., L. & W. R. R. rail section (see Fig. 107) for about a quarter of a mile. This change was made and the track put in good line and surface about the first of September, a month before the tests were started.



USUAL POSITION OF STREMMATOGRAPHS FOR THREE SUCCESSIVE SET-UPS

FIG. 31.

The site chosen for the tests was on the eastbound track. On account of the density of traffic at this point, the locomotive used in the test was not permitted to back over the test section against traffic in returning from the runs, as was done on the Illinois Central Railroad, where the test track was within the yard limits. The test section was located so that this did not seriously interfere with the tests, since a cross-over at East Dover Junction and another at the Dover station, about a mile and a half apart (both operated from towers) permitted the crossing from one track to the other for the successive runs to be made without great inconvenience or loss of time. The test section was on a light fill.

The tests were for the purpose of obtaining results on the track of a second railroad with various types of locomotives, with different ballast, different size of ties, different rail and method of spiking, as well as different density of traffic over the tracks. The wheel loads and spacing of the locomotives used are shown in Fig. 32. Tests were made with a Ten-wheel locomotive, a Mikado, and two Pacific locomotives. Of the two Pacific locomotives used, one is for passenger service and the other for fast freight service. The method of making the tests was the same as that followed on the Illinois Central Railroad and described elsewhere.

C. Reduction of Data and Accuracy of Instruments.

29. *Static Tests; Strain Gage Readings.*—In static tests, the strain gage readings, taken on the top of the base of the rails, were reduced to stresses in the extreme fiber of the base of the rail. The general process of reduction of a strain gage reading* involved the subtraction of the reading under load from the reading under zero-load, the correction of this difference by reference to the readings on an unstressed standard bar, and the reduction of the resulting corrected strain to a fiber stress at that point by multiplying the strain by a factor dependent upon the dimensions of the instrument, the gage length, and the modulus of elasticity for steel (which was taken as 30,000,000 lbs. per sq. in.). In reducing strain gage readings to stress in the extreme fiber of the base of the rail, consideration must also be given to the fact that the readings were not taken on the extreme fiber of the rail. This reduction was based on the assumption that the strain on a fiber varies directly as its distance from the neutral axis.

In general, with careful work errors of observation may be kept below 750 lbs. per sq. in. stress in steel by careful handling of the strain gage, and it is believed that the results of the strain gage observations came within this limit.

30. *Static Tests; Level Bar Readings.*—In reducing the level bar readings to deflections of rail or depressions in the ballast, the first step was to find for each point the difference between the reading under zero-load and the reading under a given load. Then, beginning at the point over the reference stake (Fig. 29), these differences were added algebraically in the order in which the readings were taken. The sum of the differences up to any point is equal to the depression of the rail

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*For a detailed discussion of the method used in reducing the data see Bulletin No. 64 of the Engineering Experiment Station of the University of Illinois, "Tests of Reinforced Concrete Buildings under Load," by A. N. Talbot and W. A. Slater; also see the Proceedings of the American Society for Testing Materials, 1913, "The Use of the Strain Gage in Testing Materials," by W. A. Slater and H. F. Moore. The accuracy of strain gage readings is discussed in the latter paper.

at that point. At the end of the section at which the readings of depressions were obtained level bar readings were taken to a second reference point. At the second reference stake, if the differences did not sum up to zero the variation from zero was taken as due to small cumulative errors of observation. Corrections for this error were distributed among the various readings.

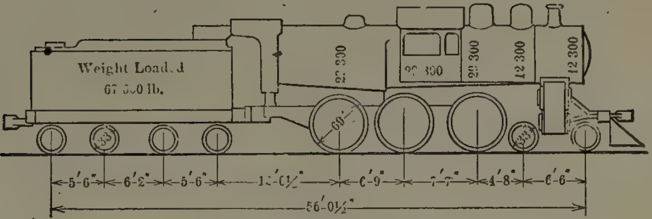
As previously stated, the measurements of the depression of the subgrade were determined by reading with the level bar from points on the rail to the depression plugs. Then for any given plug the depression of the plug with respect to the point on the rail was given by the difference between the zero-load reading and the load reading. Since the actual depression of the point on the rail was known from the readings with the level bar to the rail, the actual depression of the plug was readily obtained.

The level bar used had a length between legs of 20 in., and the level bubble moved one division along its scale for 20 seconds change in angle of inclination of the instrument. In the field the bar could be leveled so that the bubble came to rest not more than one division from the middle of its scale, and this corresponds to a change of elevation of one end of the bar with respect to the other of 0.002 in.

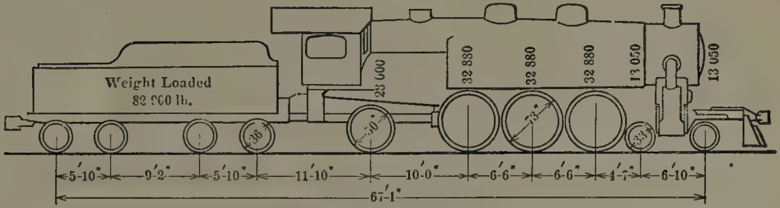
31. *Static Tests; Pressure Capsule Readings.*—The readings obtained with the pressure capsules for static tests were in terms of movement of the pointers over the dials. These readings were reduced to unit pressures in the ballast by means of calibration curves, there being a different calibration curve for each capsule.

32. *Moving Load Tests; Stremmatograph Results.*—For measuring strains from stremmatograph records a microscope fitted with a micrometer eyepiece and having a magnification of 75 diameters was used. The microscopes used in measuring strains from record discs were fitted with special rotating stages so that any portion of a record could readily be brought into the field of the microscope and the record followed by rotating the stage. The microscopes were fitted with micrometer eyepieces. The scale of each micrometer eyepiece could be moved by means of an adjusting screw, so that in taking a reading the zero of the scale could be placed over the image of the edge of the zero line on the record disc.

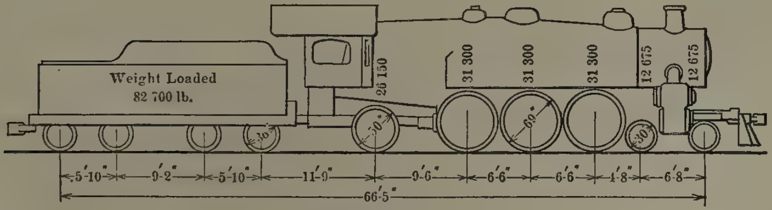
The strains were measured for points under and between wheels and the results tabulated on special data sheets. A test of the accuracy of reading by the microscope from the smoked-glass records was made by two observers in the early part of the tests. Forty-five determinations of stress from various records selected at random were made by each of the observers. The maximum deviation of any reading by a single observer from the average result obtained by the two observers was 0.000270 in., and the average deviation 0.000054 in. These values correspond to variations in unit stress in the rail of 2020 lbs. per sq. in. and 400 lbs. per sq. in., respectively. With later experience it is believed there are very few readings of the records in error more than 700 lbs. per sq. in.



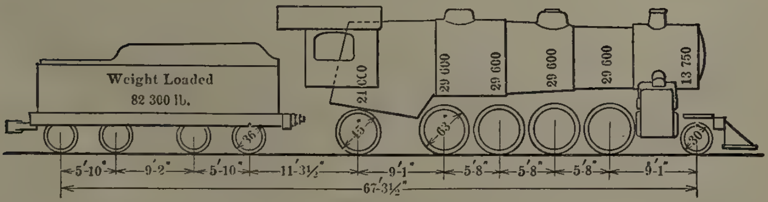
Ten-Wheel (4-6-0)



Pacific (Passenger) (4-6-2)



Pacific (Freight) (4-6-2)



Mikado (2-8-2)

DIAGRAMS OF FOUR
DELAWARE, LACKAWANNA AND WESTERN LOCOMOTIVES.
FIG. 32.

After the data had been read from the stremmatograph records, all results obtained on a given section of track by the four instruments at each speed were averaged together, the results for each side of the base of the rail being kept separate. After averaging, the mean of the stresses at the two sides of the rail was calculated, and this mean stress is the value used in plotting the diagrams and making the comparisons.

It should be noted that the values of strain measured by both the stremmatograph and the strain gage are the averages in the 4 in. gage length. For points under a load this average value may be appreciably less than the maximum value at the center of the gage line, so a correction has been applied to obtain the maximum stress. In the static load tests in which the strain gage was used, this correction was computed as follows: If f_0 is the measured stress under the load and f_1 is the measured stress at the adjacent gage line at a distance x (in inches) from the load, then it can be readily shown that the value to be added to f_0 in order to obtain the stress at the center of the gage line under the load is given by the following equation:

$$\text{Correction} = \frac{f_0 - f_1}{x - 1}$$

For the stremmatograph results no readings at adjacent gage lines were available for use in making this correction. From the static tests, however, it was found that this correction averaged practically 4 per cent. of the average stress under the load. So all of the observed stresses under wheels in the moving load tests were increased by 4 per cent. in order to obtain the stress at the center of the gage line.

33. *Moving Load Tests; Results with Recording Pressure Capsules.* —The records obtained with the recording pressure capsules were of the same general character as those obtained with the stremmatographs. In reducing these results, readings with the microscope were taken of the values of the ordinates of the diagrams under the wheels and between the wheels of the locomotive as was done with the stremmatograph records. By multiplying by the proper factor these readings were reduced to movements of the plunger rods (expressed in thousands of an inch). These quantities were then used to obtain the unit-pressure in the ballast from the calibration curves. After being computed and checked these pressures were grouped and averaged as was done with the stremmatograph results.

34. *Moving Load Tests; Photographic Measurement of Depression.* —The notes taken in connection with the photographic measurement of rail depression and tie depression included: Description of test section, speed of locomotive, condition of light, time of day, the size of the stop (diaphragm) used, the length of exposure, the distance of the camera lens from the rail, and the position of the electric contact point for operating the shutter. The reduction of the data was made by means of microscope measurements of distance between images on the developed negative of the two positions of the reference crossmarks on

the rail or on the ties. The reading of the scale in the micrometer eye-piece was reduced to inches depression of the rail or tie by the use of a constant depending on the distance of the camera lens from the rail, the focal length of the lens, the scale value of the micrometer eye-piece and the magnification used. From a comparison of results obtained by this method in static tests with results obtained by the use of the level bar, measurements of deflection with the camera apparently can be made with an error of observation not greater than 0.01 in., except at high speed or on embankment subject to much vibration. The tests on the Illinois Central Railroad, however, were made on an embankment, and for that reason considerable inconsistency was found in the tests at speed.

(IV) RESULTS OF TESTS.

35. *Form of Presentation.*—In the presentation of the results of the tests, the effort has been made to present only those matters which seem to have a bearing upon the fundamentals of track action and the problems of track and to give the essential results free as far as possible from the mass of details of the test data. When it is stated that the tests have involved the making, reading, recording and reducing of more than 250,000 observations on rail strains alone, the need for presenting only the essentials will be apparent. Generally speaking, only averages of a considerable number of values are presented. Some use of individual results will be made in the discussion on the variation of individual values from the average value. It has been thought best to present the results largely in graphical form. This method allows general comparison to be made readily. Tabular values are also given for some of the principal results.

The results presented in this report relate principally to stresses in rail and to the depression of track as a whole. The action of the tie and the transmission of pressure through ballast and roadway and other related matters must be reserved for a later report.

Data relating to depression of track under one-axle load, two-axle load, and locomotive loading under static conditions will first be given; then data on stresses in rail for these loadings and for moving load tests with locomotives; and following these a general discussion of the effect of speed, influence of rail section, effect of wheel spacing, condition of track, etc.

36. *Depression of Track Under Load.*—Flexibility, elasticity, and stiffness are important properties of railroad track. The quality of the track is affected by variations in these properties. It is apparent even to a casual observer that track depresses under wheel loads. The weight from the wheel loads is distributed by the rail among adjacent ties, and vertical pressures are set up in ties, ballast and roadway. The pressures transmitted by rail, ties, ballast, and roadway compress or otherwise deform these various parts of the track structure, the vertical deforma-

tion and movement of the different parts together forming the total track depression. Generally speaking, the action has the nature of elastic deformation, and when the wheel load is removed the track resumes its normal position, wholly or partially so according to the condition of the track and the nature and amount of load. The stiffness and flexibility of track are dependent upon the section of the rail and its flexural properties, the dimensions and spacing of the ties, and the nature, quality, and condition of the ballast and roadbed.

At this place no effort will be made to analyze the parts played by the rail, ties, ballast, and roadway in making up the track depression. The total depressions will be reported—the combined effect of rail, tie, ballast, and roadway. At another time a discussion will be made of the relation between the deformations of the several parts of the track structure. The following general statement is given as an estimate of the division of the depressions in the various parts in what may be called good track under the drivers of a Mikado locomotive: compression of the tie under the rail and effect of bending of tie to bring it to full bearing on the ballast along its length, 0.05 in.; compression of 24 in. of stone ballast immediately under the rail, 0.15 in.; compression of roadway immediately under rail, 0.15 in. The bending of the rail between the ties is slight, the deflection of the rail between two adjacent ties under the weight of the driver of a Mikado locomotive on rail of 85-lb. section amounting to not more than 0.01 in. in a tie spacing of 22 in. For heavier rail the deflection of course will be less.

Whether the magnitude of the track depression is directly proportional to the load applied or varies considerably from direct proportionality is dependent upon the nature of the track and its condition. For the best track in well-tamped condition (freshly surfaced) the tests indicate that the relation between the load and the resulting depression approaches direct proportionality; that is, the amount of the depression of the track is directly proportional to the load applied. For mediocre track and track which is not well kept up, it is evident from the results of the tests that the first part of the load applied produces a greater depression than a later equal additional increment of load. The effect of this on stresses in the track is important.

The foregoing refers to the relation between vertical pressures and the resulting vertical deformations or depressions at any point along the line of the rail both at and away from the wheel load. Away from the load the pressure of the rail on the ties will vary from tie to tie, and the consequent depression will therefore vary, but at any point the downward pressure of the rail and the upward pressure of the tie must, of course, be equal to each other. In the tests the magnitude of the track depression along the rail has been measured, and the distribution of vertical pressure among the ties may be estimated from the data obtained. Records of results will be given of track depression for one-axle load, two-axle load, and locomotive loading.

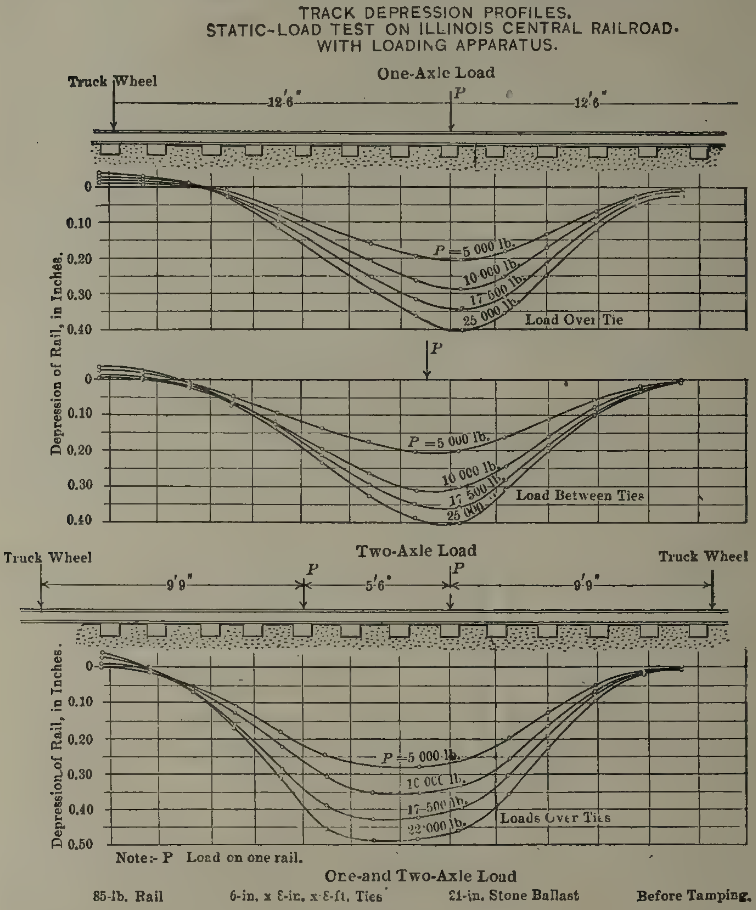
37. *Depression of Track; One-axle Load and Two-axle Load.*—In Figs. 33 to 41 are given track depression profiles for one-axle load and for two-axle loads (the axles being 66 in. apart) for tests made on the test sections of track on the Illinois Central Railroad north of Champaign. At the place where the tests with loading apparatus were made the ties were spaced 22 in. center to center. The load was applied near the middle of the length of a rail to avoid the effect of rail joints. The measurements of depression were taken on the base of the rail; the depressions reported give the vertical movement of the rail as produced by bending of rail and vertical movement of tie, ballast, and roadway. Results are given for the load applied both at a point directly over the tie and at a point between two ties. Most of the tests are on rail of 85-lb. section, but results are also given for tests on 100-lb. section and 125-lb. section. The diagrams include tests on track having a depth of broken stone ballast below the tie of 6 in., 12 in., and 24 in. Diagrams are given for freshly tamped track and for track which had borne traffic for a considerable time after being tamped. The results are given for the several magnitudes of load applied. It should be noted that the depression measurements were taken from the initial position which the track assumed with the loaded car upon it as the basis of measurement. It will be seen that when a load is applied through the loading apparatus weight is released from the trucks of the car and that the track in the vicinity of the trucks will rise accordingly. The effect of this change will appear for some distance on each side of the truck wheels and may have some effect on the track depressions well toward the center of the car.

Figs. 42 to 45 give load-depression curves for the rail at the point of application of load in the case of one-axle load and at a point midway between loads in the case of two-axle loads. The values plotted are from the same tests as those given in the depression profiles.

Little difference is to be found in the depression profiles for the load over a tie and for the load midway between ties. The depression is generally somewhat greater for the load over a tie. This is true both for one-axle load and for two-axle load.

It is seen that there is a marked difference in the magnitude of the track depression according to the condition of the track, freshly tamped track having a smaller depression under load than track which has been subjected to the action of traffic for a considerable time after being surfaced. In this report the term "after tamping" is applied to track on which trains had been run for say one to two weeks after the track had been tamped. The term "before tamping" is applied to track which had been subjected to traffic of passenger trains for say two to six months. It should be stated, however, that in all these tests the track was in excellent condition.

For freshly tamped track a straight line drawn through the origin fits fairly well the several points in the load-depression curves. In other words, the magnitude of the depression of the track is directly proportional to the load applied. This property of direct proportionality in track depressions corresponds to a constant modulus of elasticity of rail-support as will be discussed under 47, Modulus of Elasticity of Rail-Support. It will be found that the relation between the magnitude of the applied load and the magnitude of the track depression (corresponding to the quality of stiffness in properties of materials) is an important property of track and has an influential bearing on the stresses developed in the rail under applied load.


TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD.
WITH LOADING APPARATUS.

Note:- P Load on one rail.

One-and Two-Axle Load

85-lb. Rail 6-in. x 8-in. x 8-ft. Ties 21-in. Stone Ballast Before Tamping.

Fig. 33.

It is apparent from the load-depression diagrams for tests marked "before tamping" that a light load produces a relatively greater depression

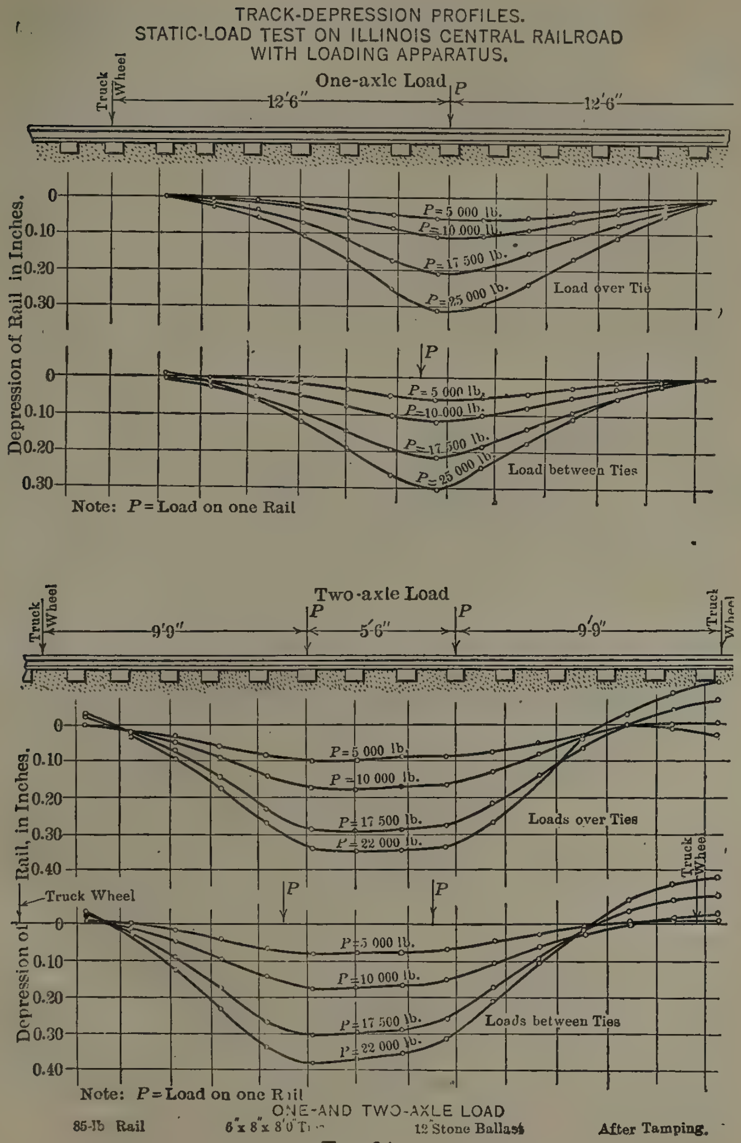
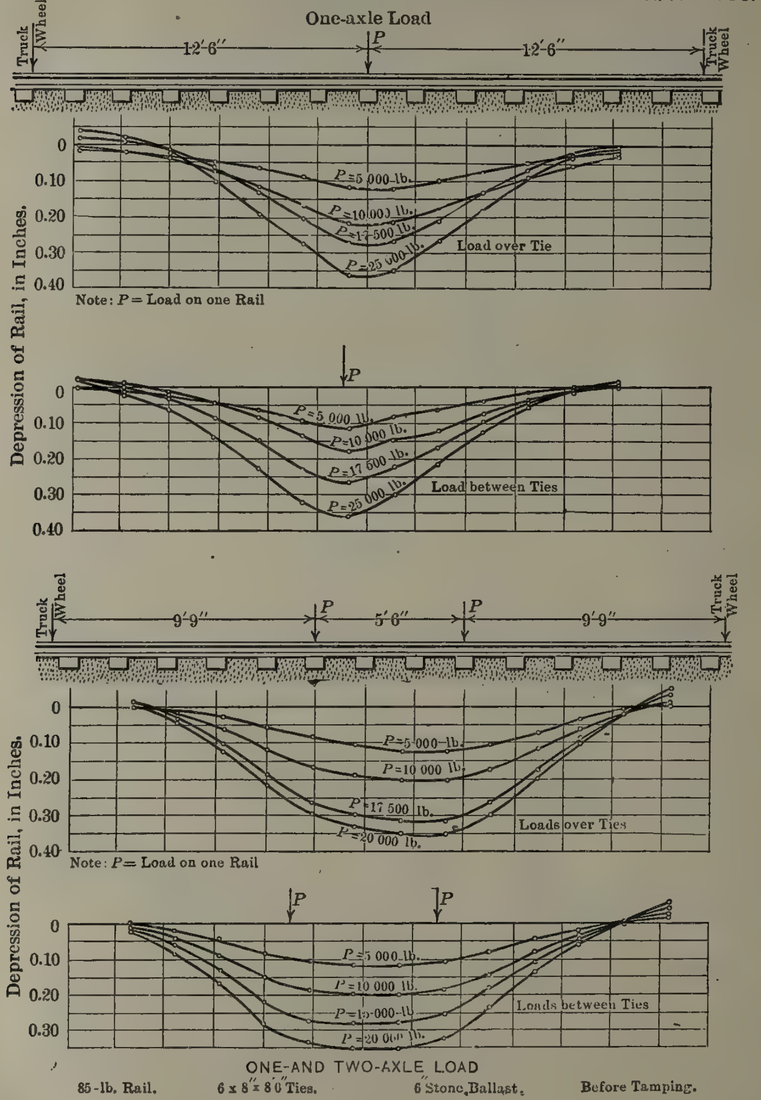

TRACK-DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.
One-axle Load
Truck Wheel
P
12'6"
12'6"
Depression of Rail in Inches.
0
0.10
0.20
0.30
P=5 000 lb.
P=10 000 lb.
P=17 500 lb.
P=25 000 lb.
Load over Tie
P
Load between Ties
Note: P=Load on one Rail
Two-axle Load
Truck Wheel
P
P
9'9"
5'6"
9'9"
Truck Wheel
Depression of Rail, in Inches.
0
0.10
0.20
0.30
0.40
P=5 000 lb.
P=10 000 lb.
P=17 500 lb.
P=22 000 lb.
Loads over Ties
Truck Wheel
Truck Wheel
P
P
Loads between Ties
Note: P=Load on one Rail
ONE-AND TWO-AXLE LOAD
85-lb Rail
6"x 8"x 8'0" Ties
12" Stone Ballast
After Tamping.

FIG. 34.



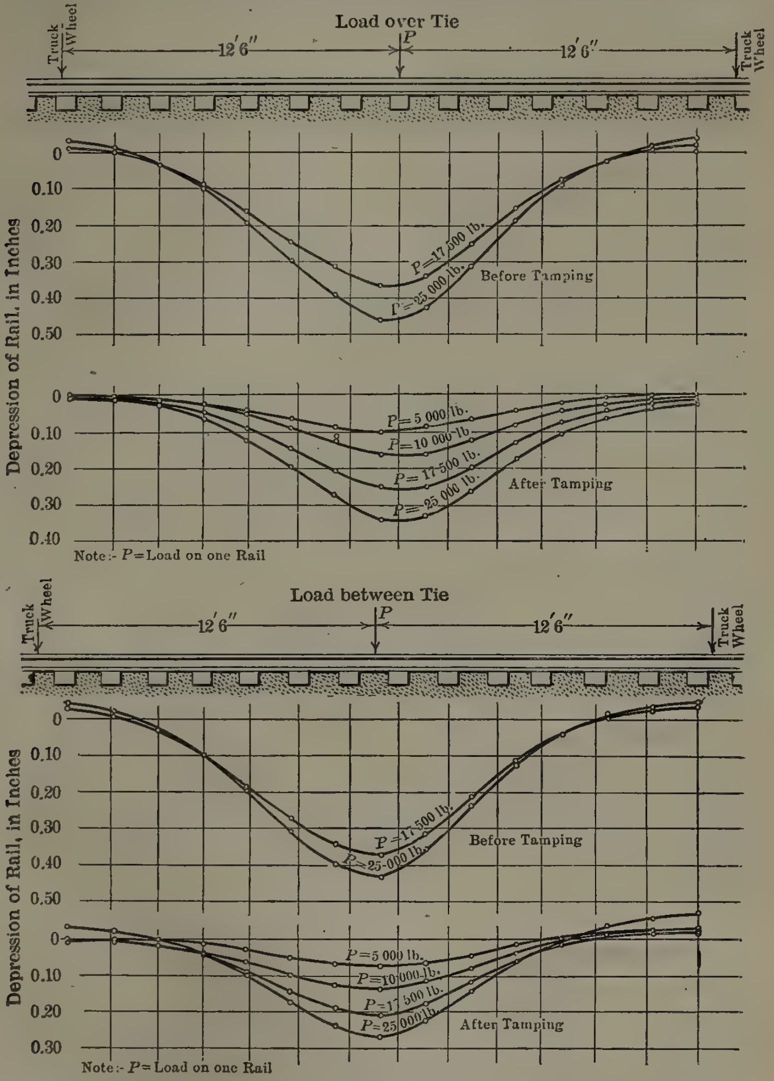
TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

One-axle Load

ONE-AND TWO-AXLE LOAD

Fig. 35.

TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.



ONE-AXLE LOAD

85-lb. Rail 7" x 9" x 8' 0" Ties 12" Stone Ballast

FIG. 36.

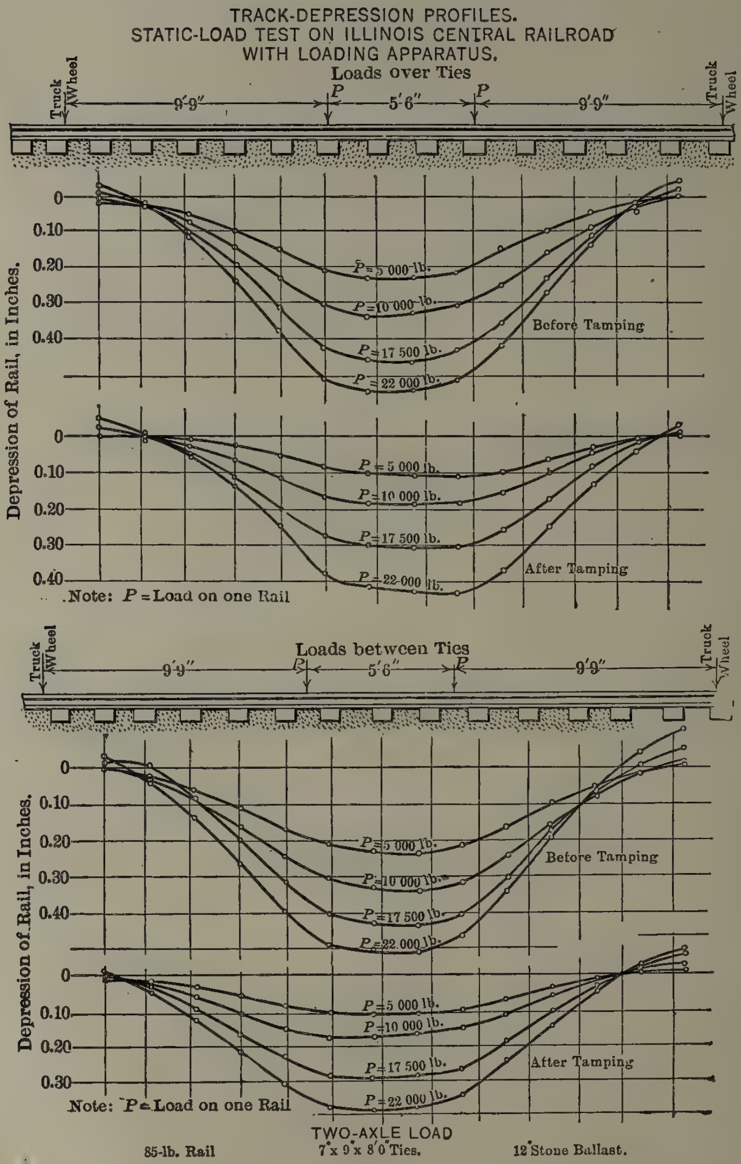

TRACK-DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.
Loads over Ties
Truck Wheel
9′-9″
P
5′-6″
P
9′-9″
Truck Wheel
Depression of Rail, in Inches.
0
0.10
0.20
0.30
0.40
P = 5 000 lb.
P = 10 000 lb.
P = 17 500 lb.
P = 22 000 lb.
Before Tamping
0
0.10
0.20
0.30
0.40
P = 5 000 lb.
P = 10 000 lb.
P = 17 500 lb.
P = 22 000 lb.
After Tamping
Note: P = Load on one Rail
Loads between Ties
Truck Wheel
9′-9″
P
5′-6″
P
9′-9″
Truck Wheel
Depression of Rail, in Inches.
0
0.10
0.20
0.30
0.40
P = 5 000 lb.
P = 10 000 lb.
P = 17 500 lb.
P = 22 000 lb.
Before Tamping
0
0.10
0.20
0.30
P = 5 000 lb.
P = 10 000 lb.
P = 17 500 lb.
P = 22 000 lb.
After Tamping
Note: P = Load on one Rail
TWO-AXLE LOAD
85-lb. Rail
7″ x 9″ x 8′ 0″ Ties.
12″ Stone Ballast.

FIG. 37.

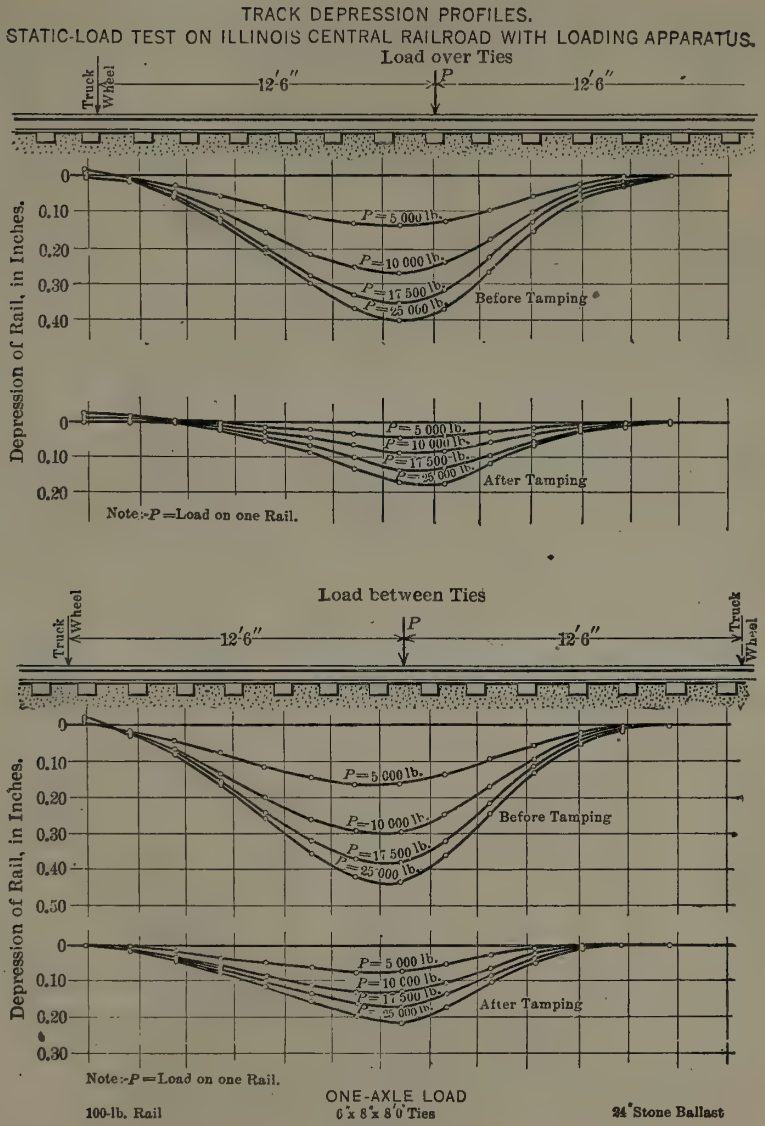

TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.
Load over Ties
Truck
Wheel
12′6″
P
12′6″
Depression of Rail, in Inches.
0
0.10
0.20
0.30
0.40
P=5 000 lb.
P=10 000 lb.
P=17 500 lb.
P=25 000 lb.
Before Tamping
0
0.10
0.20
P=5 000 lb.
P=10 000 lb.
P=17 500 lb.
P=25 000 lb.
After Tamping
Note:-P=Load on one Rail.
Load between Ties
Truck
Wheel
12′6″
P
12′6″
Truck
Wheel
Depression of Rail, in Inches.
0
0.10
0.20
0.30
0.40
0.50
P=5 000 lb.
P=10 000 lb.
P=17 500 lb.
P=25 000 lb.
Before Tamping
0
0.10
0.20
0.30
P=5 000 lb.
P=10 000 lb.
P=17 500 lb.
P=25 000 lb.
After Tamping
Note:-P=Load on one Rail.
ONE-AXLE LOAD
100-lb. Rail
6″x 8″x 8′0″ Ties
24″ Stone Ballast

FIG. 38.

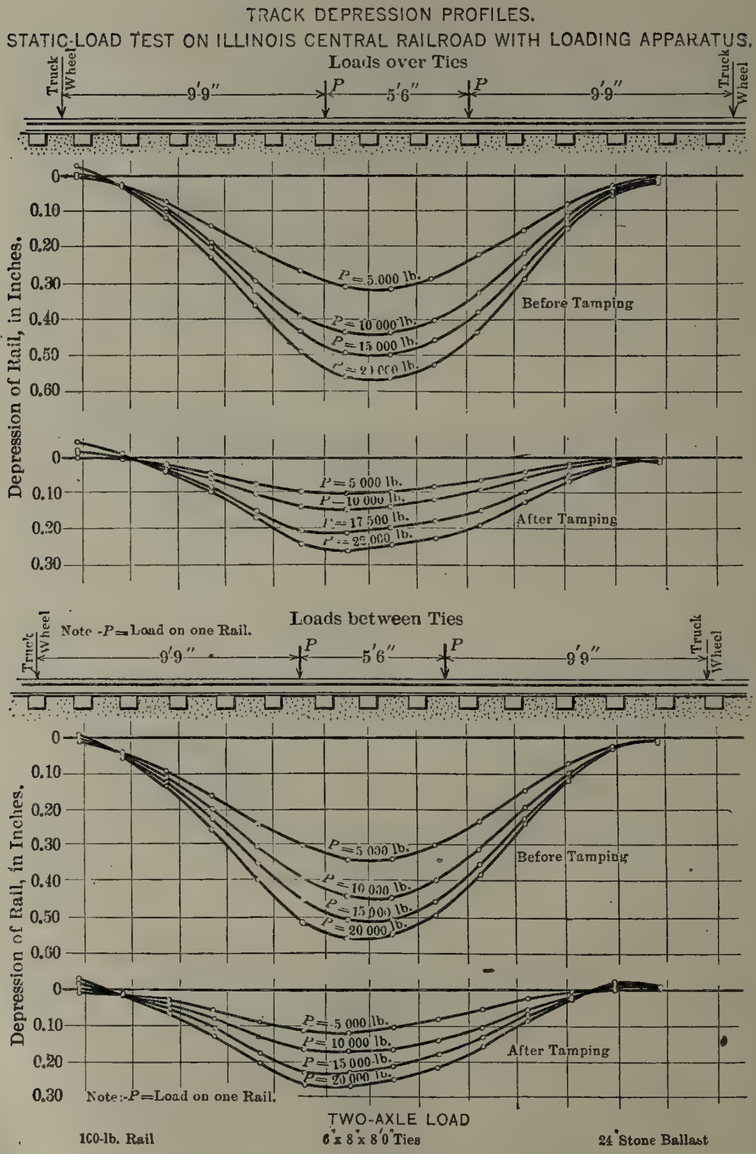
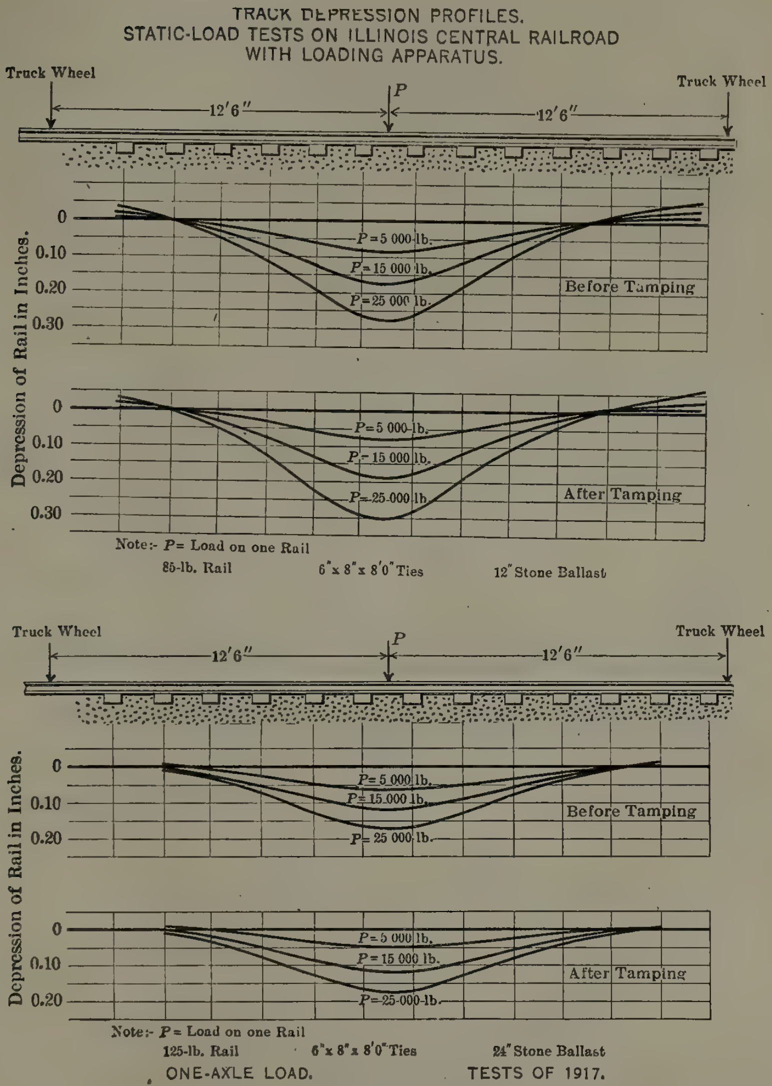
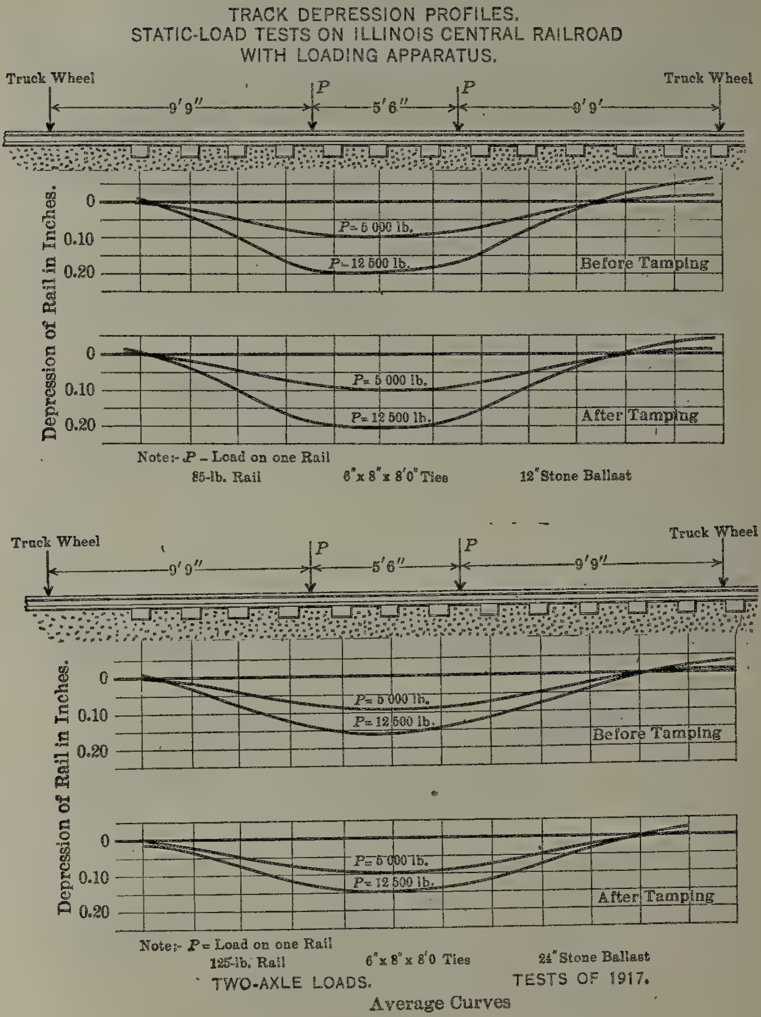

TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.
Loads over Ties
Truck Wheel
9′9″
P
5′6″
P
9′9″
Truck Wheel
Depression of Rail, in Inches.
0
0.10
0.20
0.30
0.40
0.50
0.60
P = 5 000 lb.
P = 10 000 lb.
P = 15 000 lb.
P = 20 000 lb.
Before Tamping
P = 5 000 lb.
P = 10 000 lb.
P = 17 500 lb.
P = 22 000 lb.
After Tamping
Loads between Ties
Note - P = Load on one Rail.
P = 5 000 lb.
P = 10 000 lb.
P = 15 000 lb.
P = 20 000 lb.
Before Tamping
P = 5 000 lb.
P = 10 000 lb.
P = 15 000 lb.
P = 20 000 lb.
After Tamping
Note: - P = Load on one Rail.
TWO-AXLE LOAD
100-lb. Rail
6″ x 8″ x 8′0″ Ties
24″ Stone Ballast

FIG. 39.



Average Curves

FIG. 40.



TRACK DEPRESSION PROFILES.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.

Note:- P – Load on one Rail
85-lb. Rail 6″ x 8″ x 8′0″ Ties 12″ Stone Ballast

Note:- P = Load on one Rail
125-lb. Rail 6″ x 8″ x 8′0 Ties 24″ Stone Ballast

TWO-AXLE LOADS. TESTS OF 1917.

Average Curves

Fig. 41.

LOAD-DEPRESSION DIAGRAMS.

STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Ties	6 in. x 8 in. x 8 ft.	6 in. x 8 in. x 8 ft.	6 in. x 8 in. x 8 ft.	7 in. x 9 in. x 8 ft.
Ballast	24 in.	12 in.	6 in.	12 in.
Tamping	Before	After	Before	After and Before

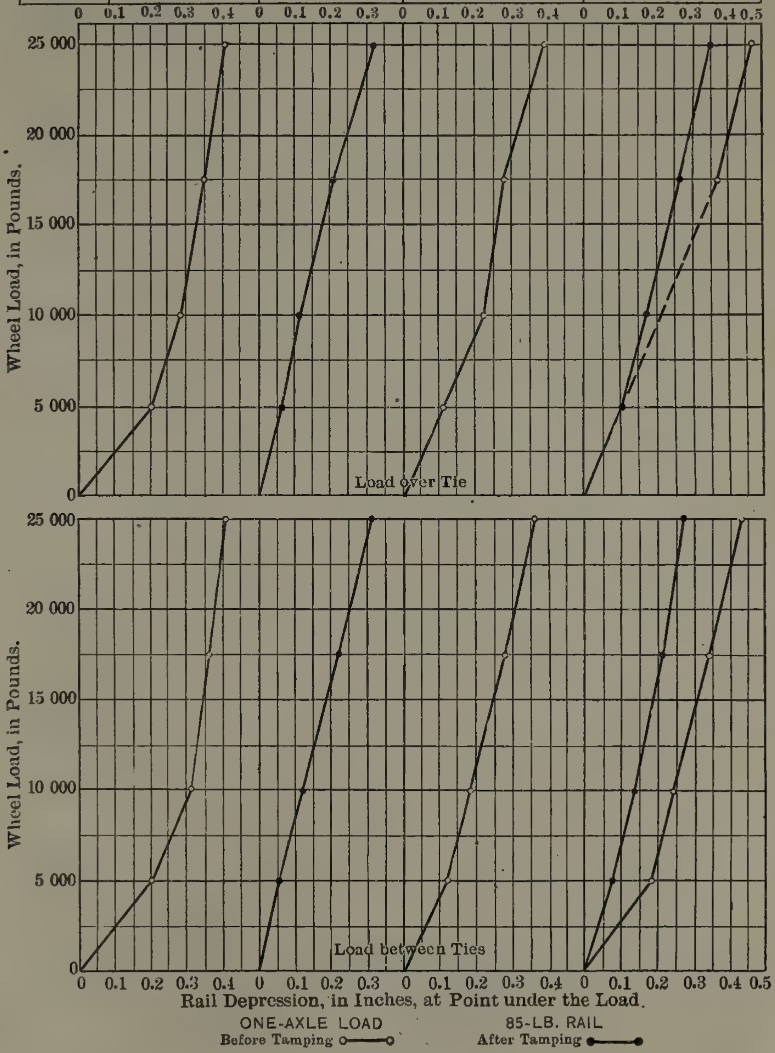


FIG. 42.

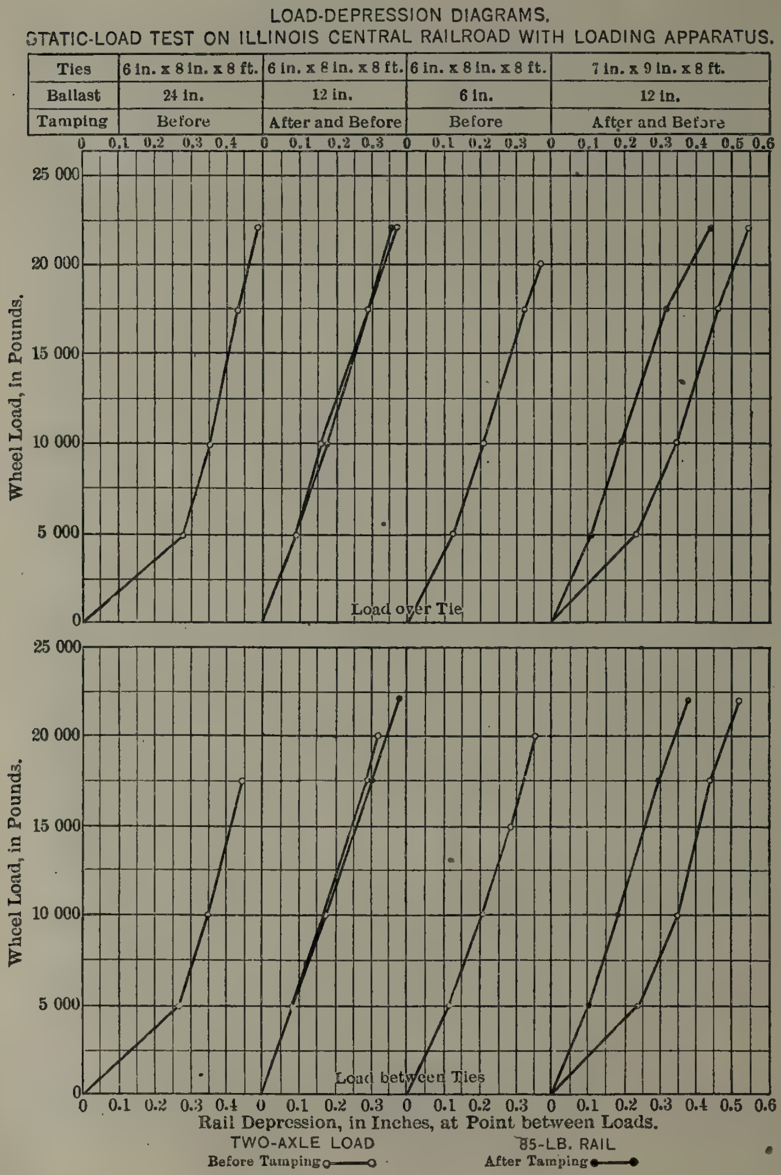

LOAD-DEPRESSION DIAGRAMS.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.
Ties
6 in. x 8 in. x 8 ft.
6 in. x 8 in. x 8 ft.
6 in. x 8 in. x 8 ft.
7 in. x 9 in. x 8 ft.
Ballast
24 in.
12 in.
6 in.
12 in.
Tamping
Before
After and Before
Before
After and Before
0 0.1 0.2 0.3 0.4 0 0.1 0.2 0.3 0 0.1 0.2 0.3 0 0.1 0.2 0.3 0.4 0.5 0.6
25 000
20 000
15 000
10 000
5 000
0
Wheel Load, in Pounds.
Load over Tie
Load between Ties
Rail Depression, in Inches, at Point between Loads.
TWO-AXLE LOAD
85-LB. RAIL
Before Tamping
After Tamping

FIG. 43.

LOAD-DEPRESSION DIAGRAMS.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.

Ties	6 in. x 8 in. x 8 ft.	6 in. x 8 in. x 8 ft.
Ballast	24 in.	24 in.
Tamping	After and Before	After and Before

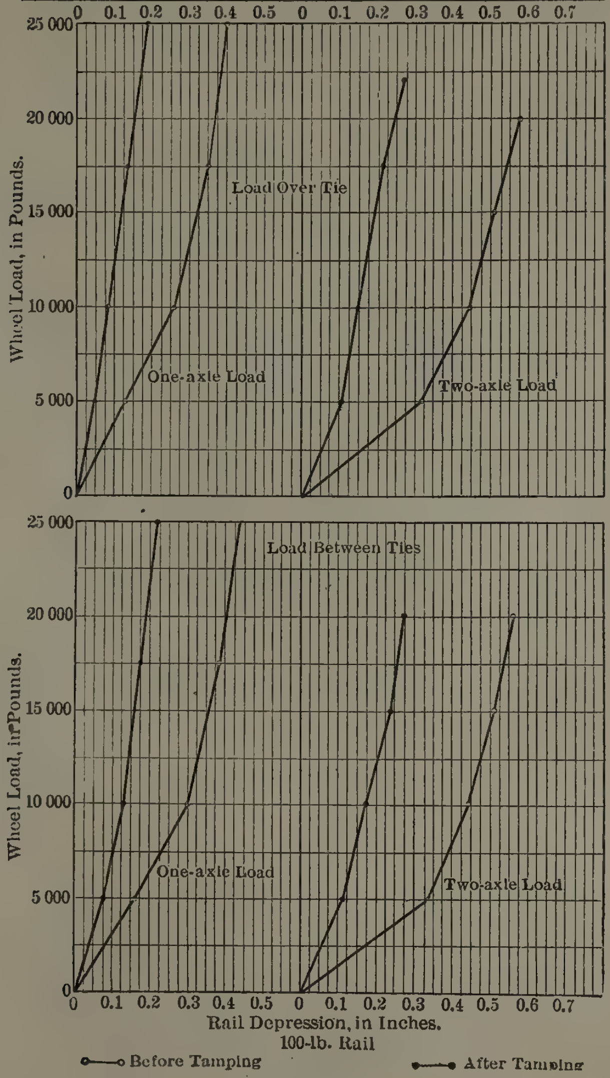


FIG. 44.

than is given by later increments of load. It thus appears that the stiffness of the rail-support is smaller for the lighter loads. In the load-depression diagrams for condition "before tamping" a straight line may be drawn which will fit fairly well the points for the highest three loads. This line will intersect the line for zero-load at the right of the point representing zero-depression. This distance or intercept may be thought to be in the nature of play or looseness in the track. It is probably nearer correct to say that in the lower part of the diagram the track is least resistant to load (less stiff from the standpoint of elastic action), and that for the smaller loads the depression produced is not proportional to the load applied. If there is play in the test sections of track, it would seem most likely to be between the tie and the ballast immediately under the rail and adjacent thereto, so that the tie must bend before it comes to a full and even bearing along its length, and part of the resistance for the lighter loads may be that of the flexural resistance of the tie. It will be noted that a straight line drawn through the upper points of a load-depression curve for "before tamping" is approximately parallel to the corresponding line for freshly tamped track at the same location. The distance from the point of zero-depression to the point where the line

LOAD-DEPRESSION DIAGRAMS.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Rail	85-lb.	125-lb.	85-lb.	125-lb.
Ties	6-in. x 8-in. x 8-ft.	6-in. x 8-in. x 8-ft.	6-in. x 8-in. x 8-ft.	6-in.x8-in.x8-ft.
Ballast	12-in.	24-in.	12-in.	24-in.

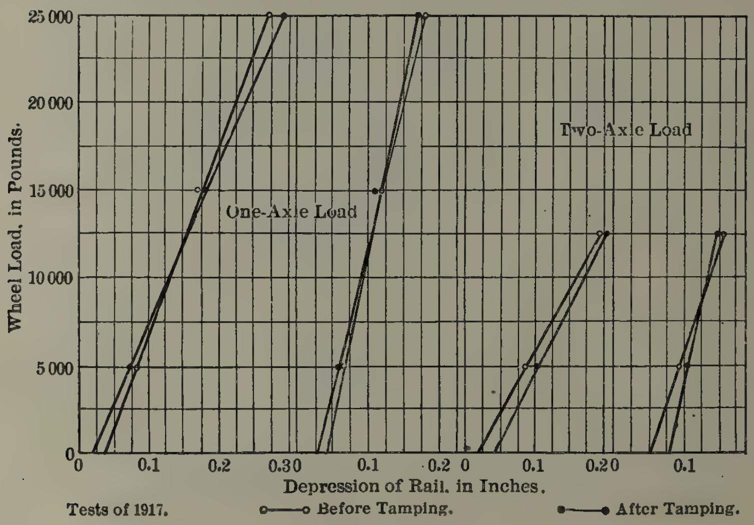


Fig. 45.

above referred to crosses the line of zero-load has been found to be as much as 0.20 in. in the track tested, though it more generally runs from 0.03 in. to 0.10 in. in track not freshly tamped. How large this value may become in poorly conditioned track is an interesting question. The effect which the variation in stiffness of track found at the several points of the load-depression curves has upon the stresses developed in the rail, upon the division of pressure among the ties, and upon the distribution of pressure over ballast and roadway is a matter for future consideration, as is also the effect produced by changes in the magnitude of the load itself.

The same variation from direct proportionality between track depression and load (constant modulus of elasticity of rail-support) is also shown in the depression profiles for track before tamping in that the magnitudes of the depression for the smaller loads are greater accordingly than for the larger loads. The effect is noticeable along the rail at each side of the load.

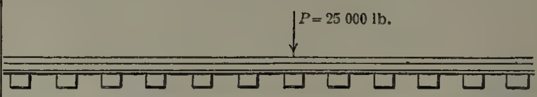
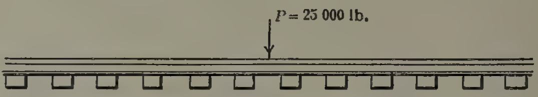
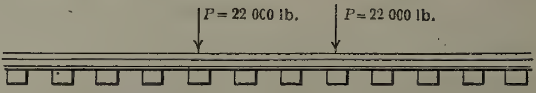
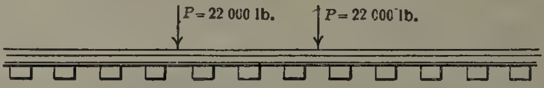
The track depression profiles for one-axle load are of interest in showing the extent of influence of the rail in carrying load to the near-by ties and in depressing them—the curve of flexure of the rail and the vertical movement of the ties fitting to each other. It may not be expected that the distance from the load to the point of zero-depression of rail (also point of zero-pressure on ties) can be accurately and definitely determined by tests of this nature since the slope of the curve of flexure is very slight for some distance on each side of this point. Besides, as has already been mentioned, by the arrangement for applying the load through the jacks an equal amount of weight was released from the trucks of the car and the effect of the release of load in causing the track to rise extended some distance from the wheels of the car.

An examination of the depression profiles for the one-axle load shows that the track depression caused by a given load on a rail of heavy section is less than that found for the lighter rail section at the same load. The load-depression diagrams also show this.

It is plain that the heavier and stiffer rail will distribute the load to a greater number of ties, though the effect is not well shown by the diagrams because of the influence of varying load on the car truck and the corresponding influence on track depression in its vicinity.

The depression profiles and the load-depression diagrams show that the maximum track depression for the two-axle load is greater than for a one-axle load with the same wheel load. For the wheel spacing used the effect of one wheel load in contributing to tie pressures along the rail extends beyond the other wheel load. In Fig. 46 typical track depression profiles (shown by light lines) from one-axle load tests are plotted in duplicate as for axle loads 66 inches apart. These have been combined by summation into composite profiles as for two-axle loads with this wheel spacing of 66 inches (shown as dotted lines). The heavy full lines are depression profiles found from the two-axle load tests. It is seen that there is close agreement between the composite curve and the profile of the two-axle load test. Comparing the diagram for 85-lb. rail with that of a single truck in Fig. 9, which is a composite diagram for two one-axle loads obtained from analysis, it is seen that there is fair agreement with the results obtained in the tests.

TABLE 2.—TIE REACTIONS, IN TERMS OF WHEEL LOAD, *P*.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH
LOADING APPARATUS.

Weight of Rail, in Pounds per Yard.	Size of Ties, in Inches.	Depth of Ballast in Inches.	ONE-AXLE LOAD  											
85	6 x 8	12	-----	0.007	0.035	0.073	0.119	0.167	0.196	0.167	0.119	0.073	0.035	0.007
85	7 x 9	12	0.007	0.018	0.037	0.069	0.112	0.164	0.186	0.164	0.112	0.069	0.037	0.018
100	6 x 8	24	------	------	0.015	0.052	0.115	0.193	0.248	0.193	0.115	0.052	0.015	-------
125	6 x 8	24	-----	------	------	0.038	0.116	0.217	0.256	0.217	0.116	0.038	------	-------
			ONE-AXLE LOAD  											
85	6 x 8	12	------	0.011	0.036	0.091	0.155	0.215	0.215	0.155	0.091	0.036	0.011	-------
85	7 x 9	12	------	-------	0.009	0.079	0.166	0.245	0.245	0.166	0.079	0.009	-----	-------
100	6 x 8	24	------	0.011	0.038	0.082	0.152	0.216	0.216	0.152	0.082	0.038	0.011	--------
125	6 x 8	24	-----	-------	0.028	0.087	0.165	0.220	0.220	0.165	0.087	0.028	------	--------
			TWO-AXLE LOAD  											
85	6 x 8	12	-------	0.035	0.126	0.228	0.293	0.317	0.317	0.293	0.228	0.126	0.035	-------
85	7 x 9	12	------	0.037	0.113	0.215	0.306	0.328	0.328	0.306	0.215	0.113	0.037	-------
125	6 x 8	24	------	0.024	0.108	0.227	0.311	0.330	0.330	0.311	0.227	0.108	0.024	-------
			TWO-AXLE LOAD  											
85	6 x 8	12	-------	0.070	0.162	0.271	0.332	0.332	0.332	0.271	0.162	0.070	------	-------
85	7 x 9	12	0.012	0.081	0.171	0.262	0.314	0.320	0.314	0.262	0.171	0.081	0.012	-----
125	6 x 8	24	-------	0.013	0.157	0.281	0.342	0.352	0.342	0.281	0.157	0.043	------	------

Attention is called to the fact that in the tests with two-axle loads (85-lb. rail) there is no reversal of curvature visible between the load points. For a less stiff rail or for a greater wheel spacing than 5 ft. 6 in. reversal of curvature may be obtained. It will be noted that the rail of 100-lb. and that of 125-lb. section give a smaller maximum depression than the rail of 85-lb. section. It should also be noted that the slope of the curve of flexure under a wheel load is less for the heavier rail than for the lighter rail.

Table 2 gives tie reactions expressed as proportional parts of the wheel load. These values have been calculated from the depression profiles by adding the depressions for the several ties and determining the proportion which the depression at each tie bears to their sum. The table is helpful in giving an idea of the loads which come upon the several ties for both the one-axle load and the two-axle load. The calculations are based upon tests on freshly tamped track and assume that tie pressures are proportional to depressions. The conditions of the tests are not such as to permit conclusions to be drawn relative to the effect of stiffness of rail upon the distribution of load to ties.

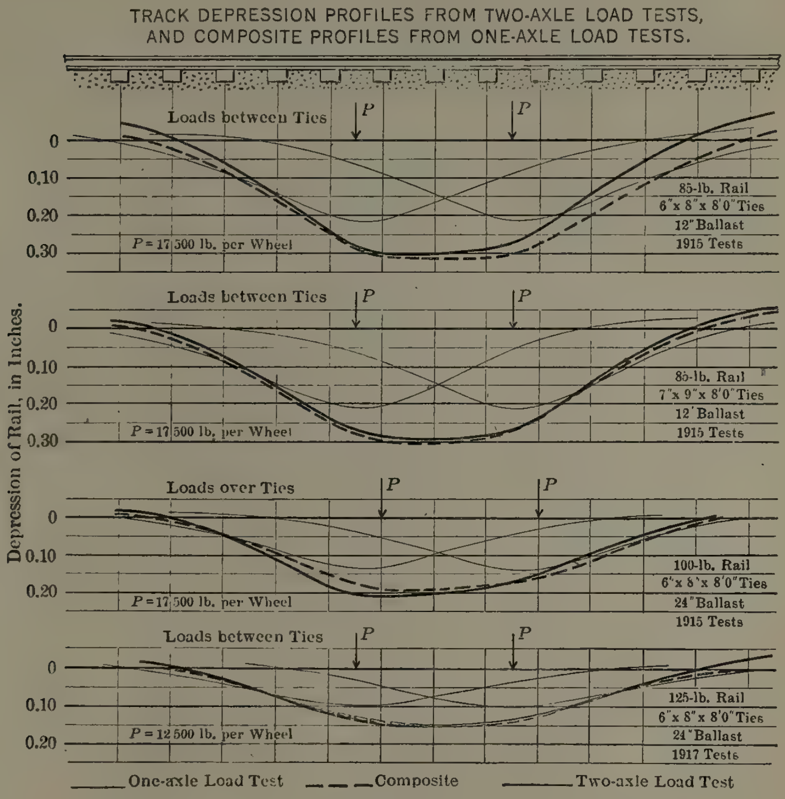
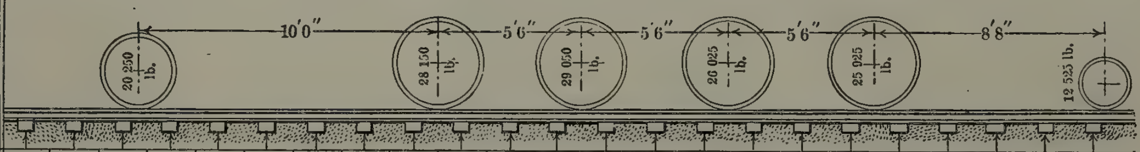


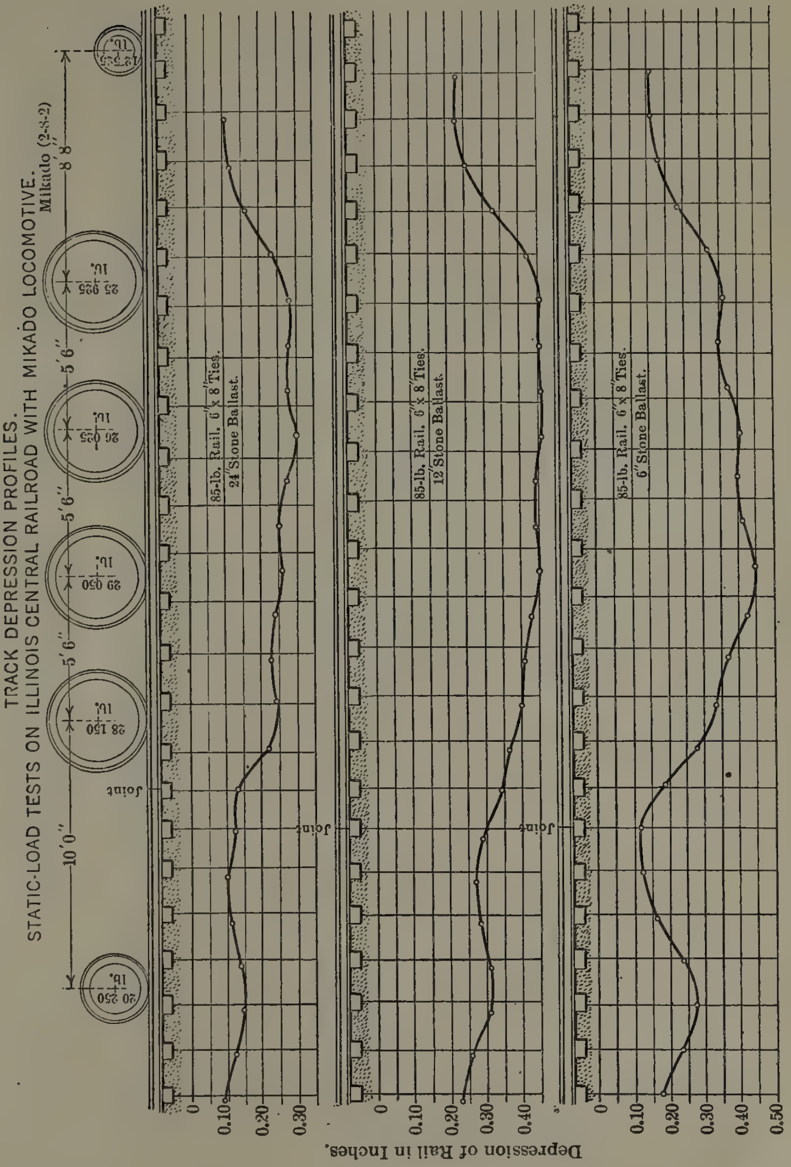
FIG. 46.

38. *Depression of Track; Static Load Test With Mikado Locomotive.*—In Figs. 47 and 48 are given track depression profiles for static loading obtained with the Mikado locomotive on rail of 85-lb. section and

TABLE 3.—TIE REACTIONS, IN THOUSANDS OF POUNDS.
STATIC-LOAD TEST ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.



Weight of Rail, in Pounds per Yard.	Size of Ties, in Inches	Kind of Ballast, and depth, in Inches.																							
85	6 x 8	24 Stone	3.1	4.0	4.9	4.4	3.5	3.5	3.8	4.2	6.6	7.9	7.4	8.2	8.5	8.5	9.7	9.3	9.1	9.3	7.6	4.9	3.7	3.3	3.5
85	7 x 9	12 Stone	3.5	4.5	5.7	6.0	4.3	3.5	3.4	4.5	6.4	7.0	6.7	7.1	7.8	7.8	8.3	8.8	8.4	8.3	7.5	5.6	6.5	6.0	6.5
85	6 x 8	12 Stone	3.1	4.5	5.3	5.2	4.8	4.7	5.1	5.8	6.2	6.7	7.0	7.5	7.7	7.7	7.8	7.8	7.7	7.8	7.0	5.6	4.1	3.8	4.0
85	6 x 8	6 Stone	3.9	5.2	6.0	5.2	3.5	2.7	2.6	4.0	6.5	7.4	8.2	9.6	9.6	8.9	8.8	8.5	7.5	7.8	7.1	5.1	3.9	3.4	3.3



TRACK DEPRESSION PROFILES.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

FIG. 47.

100-lb. section on the test sections of track on the Illinois Central Railroad north of Champaign. For the rail of 85-lb. section tests were made on three depths of ballast and two sizes of ties; for the 100-lb. section test was made on one depth of ballast. In all of these tests the track was in freshly tamped condition. It will be seen that the depression at the points between drivers is nearly as much as that directly under a driver. Calculations have been made to find the load carried by each tie along the wheel base on the assumption that there is direct proportionality of tie reaction to track depression, an assumption which is not far from correct for the condition of the track at the time of the tests. The resulting tie reactions are given in Table 3.

In Fig. 48 is given a depression profile from a preliminary test on a piece of track which had not been specially prepared for the tests. Although not recently tamped this track was apparently in good condition. The ties were partly oak and partly soft wood, and the spacing was only fairly uniform. The maximum depression is greater than that found with the specially prepared test track. Fig. 48 also gives a depression profile for track on cinder ballast about 6 in. deep below the ties. Here again the track had not been recently tamped, and it is not known what part of the increased depression results from play or smaller stiffness at low loads.

39. *Depression of Track; Static Load Tests With Switching Locomotive.*—Among the preliminary tests on the Illinois Central Railroad was one with a switching locomotive, shown in Fig. 30. Fig. 49 gives depression profiles for tests with this locomotive on stone ballasted track and cinder ballasted track at the places just reported for the Mikado locomotive and with the track in the same condition as during those tests. The effect of absence of truck and trailer is quite marked. In Fig. 49 is also given depression profile for this switching locomotive on a piece of branch line which is laid with old 56-lb. rail and which is ballasted with cinders. Attention is called to the very great track depression under the drivers. The track had not been recently tamped and probably was not in very good condition. It should be stated that locomotives of the type used in this test are not run over this branch line.

40. *Depression of Track of the Delaware, Lackawanna & Western Railroad.*—Tests were made on the track of the Delaware, Lackawanna & Western Railroad near Dover, New Jersey, to determine depression of track under the trucks of a car. A light car and a loaded car of the same kind were used. Measurements were made by means of a level bar. The depression profile is given in Fig. 50. Interferences by traffic prevented the making of tests as complete as those made on the Illinois Central Railroad. It will be seen that this track shows less depression for a given load than the track of the Illinois Central Railroad.

41. *Stresses in Rail.*—The stresses reported here are calculated from values of the strains measured in the top of the base of the rail for the static load tests and at a point below the edge of the base of the rail for

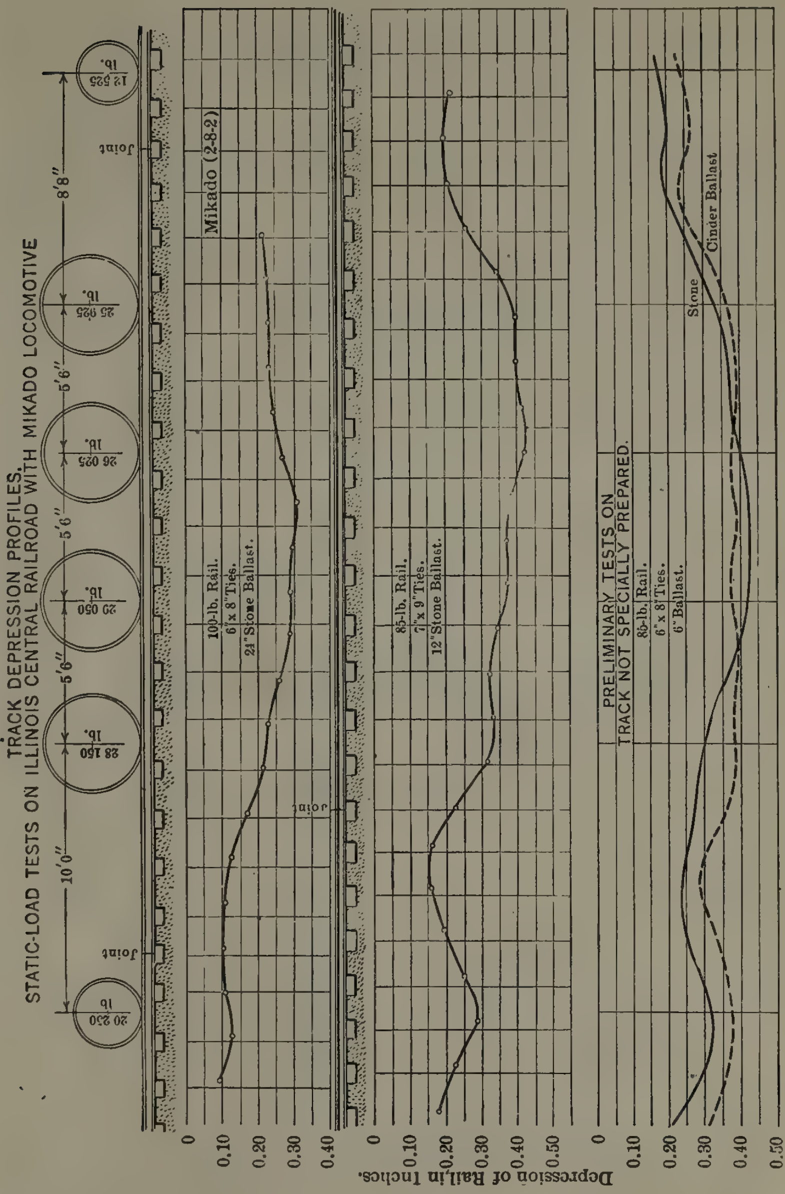

STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE
TRACK DEPRESSION PROFILES.
20 250 lb.
28 150 lb.
29 050 lb.
26 025 lb.
25 925 lb.
12 525 lb.
10'0"
5'6"
5'6"
5'6"
8'8"
Joint
Joint
Joint
Mikado (2-8-2)
100-lb. Rail.
6"x 8" Ties.
24" Stone Ballast.
85-lb. Rail.
7"x 9" Ties.
12" Stone Ballast.
PRELIMINARY TESTS ON
TRACK NOT SPECIALLY PREPARED.
85-lb. Rail.
6"x 8" Ties.
6" Ballast.
Stone
Cinder Ballast
0
0.10
0.20
0.30
0.40
0
0.10
0.20
0.30
0.40
0.50
0
0.10
0.20
0.30
0.40
0.50
Depression of Rail, in Inches.

FIG. 48.

TRACK DEPRESSION PROFILES.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH SWITCHING LOCOMOTIVE.

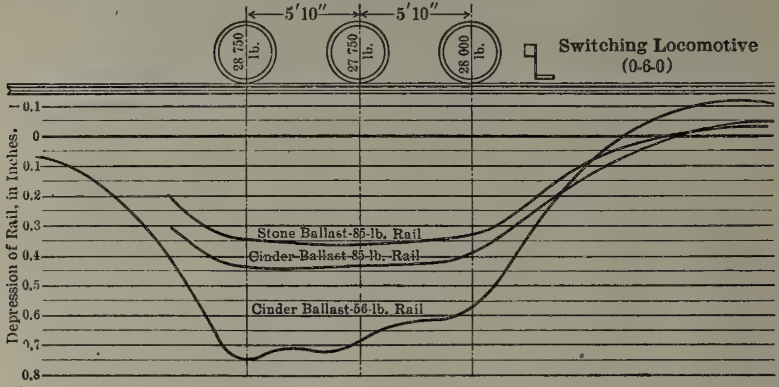
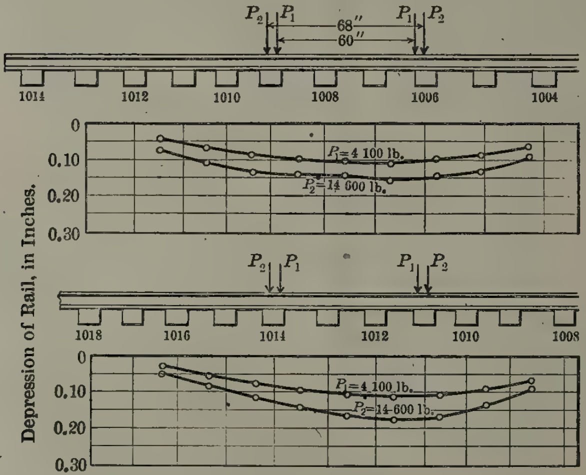


FIG. 49.

TRACK DEPRESSION PROFILES.
STATIC-LOAD TEST ON DELAWARE, LACKAWANNA
AND WESTERN RAILROAD.



Note:- P = Load on one Rail.

D.L. & W. R.R.—TWO-AXLE LOAD.

105-lb. Rail. 7′x9′x8′ 6″ Ties. 18″ Trap Ballast.

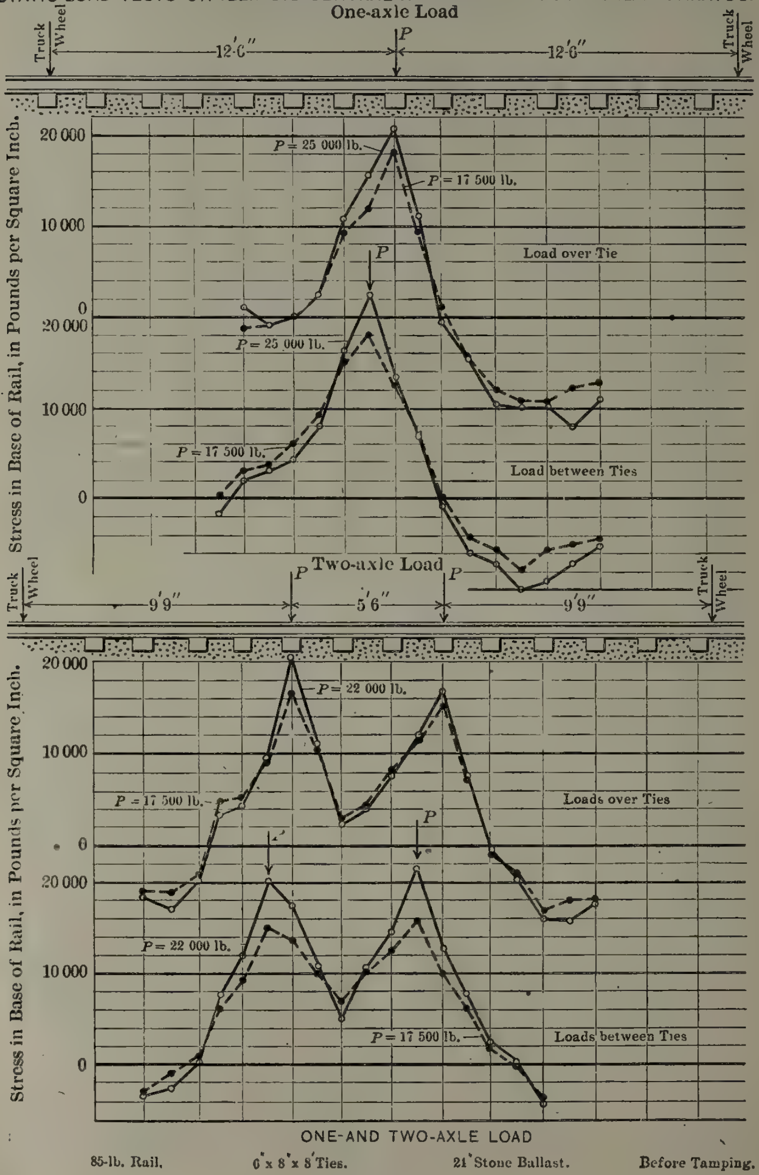
FIG. 50.

the moving load tests. As already stated, the transformation from strain to stress is made by using a modulus of elasticity of 30,000,000 lbs. per sq. in. The stresses reported are those at the remotest fiber of base of rail, the reduction being made by assuming the neutral axis to pass horizontally through the center of gravity of the rail section. In the static load test the strains were measured on one side only of the base of rail, except in the test made in 1917 when measurements were made on both sides. Not much variation between the strains at the two edges of the base of rail is to be expected when the loads are applied by means of the loading apparatus. However, as will be shown later, when a locomotive is used as load, whether stationary or in motion, a considerable variation was found in the strains at the two edges of the base of rail. It should be noted that in these results no attention was given to the bearing stresses produced by the concentration of wheel load on the top of rail nor to stresses due to lateral torsion of the rail. In general in the moving load tests the stress reported is the average of many observations and not the maximum found for an individual test. The variation of individual tests from the average will be discussed later. Although the measurements made give the total deformation in a gage length of four inches and the stress corresponding to the measured strain would represent an average stress over this gage length, the observations have been reduced, as described in 32, Moving Load Tests, Stremmatograph Results, and all the stresses given are those for a point at the middle of the 4-in. gage length.

42. *Stresses in Rail; One-axle Load and Two-axle Load.*—Figs. 51 to 59 give stress distribution diagrams for one-axle load and two-axle loads (the axles being 66 inches apart) for tests made on the test sections of track on the Illinois Central Railroad north of Champaign, Illinois. The data were obtained at the same test sections and at the same time and under same conditions as the data on track depressions already given. It will be seen also that the release of load on the truck wheels of the car through the application of pressure by the loading jacks affected the stresses in rail for some distance away from the wheels and thus that the results found at points some distance away from the load points may not be expected to represent accurately the stresses produced by the one-axle load and the two-axle loads. Measurements of strains were made with the load at a point over the tie and between ties. As previously stated in all tests before 1917 measurements of strains were made on only one side of the rail. The results given for tests made in 1917 are averages of measurements on two sides of the rail.

Figs. 60 to 63 give load-stress diagrams for gage lines at the point of application of load in the case of one-axle load and at the points of load in the case of two-axle loads, the average of the stresses at the two points being taken in the latter case. The values plotted are the same as those given in the stress distribution diagrams for a point under the load.

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

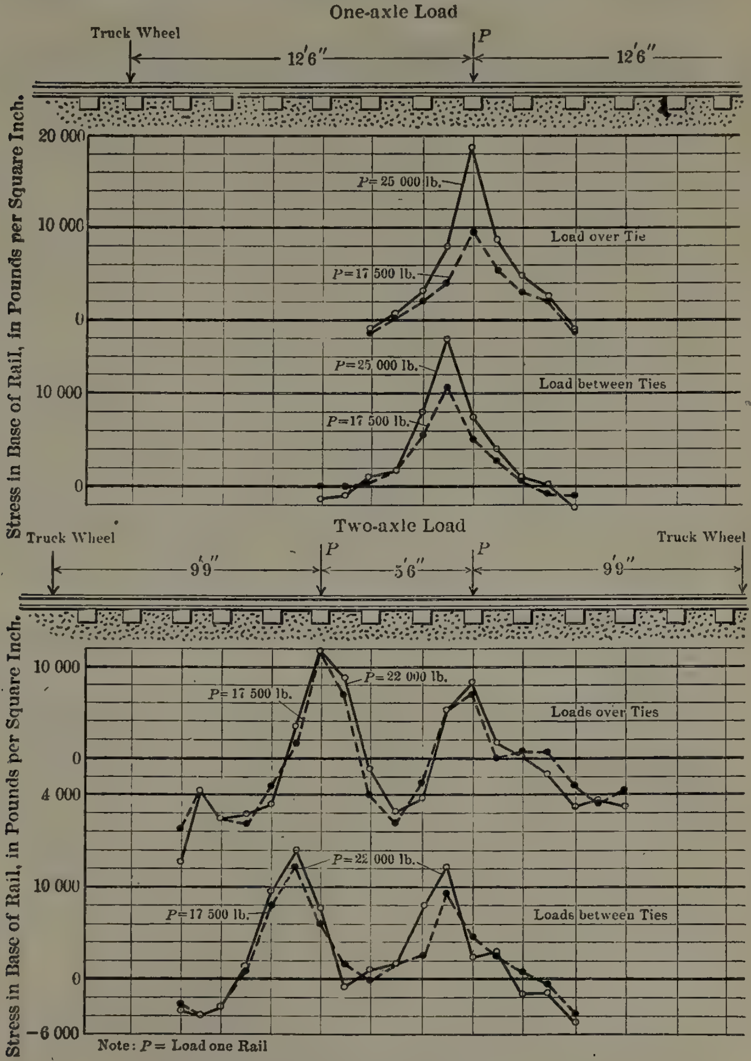


ONE-AND TWO-AXLE LOAD

85-lb. Rail. 6″ x 8″ x 8′ Ties. 21″ Stone Ballast. Before Tamping.

FIG. 51.

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.



ONE-AND TWO-AXLE LOAD

85-lb. Rail. 6″x8″x8′ Ties. 12″ Stone Ballast. After Tamping.

Fig. 52.

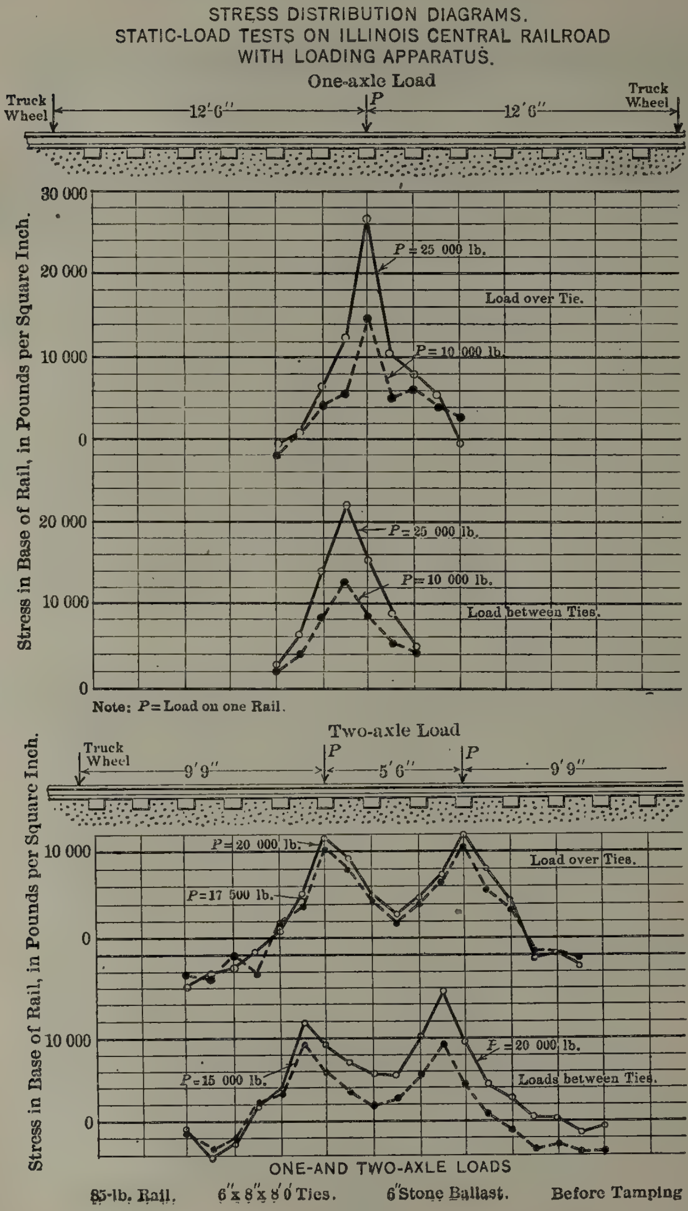

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.
One-axle Load
Truck Wheel
12′6″
P
12′6″
Truck Wheel
30 000
20 000
10 000
0
20 000
10 000
0
Stress in Base of Rail, in Pounds per Square Inch.
P = 25 000 lb.
Load over Tie.
P = 10 000 lb.
P = 25 000 lb.
P = 10 000 lb.
Load between Ties.
Note: P = Load on one Rail.
Two-axle Load
Truck Wheel
9′9″
P
5′6″
P
9′9″
10 000
0
10 000
0
Stress in Base of Rail, in Pounds per Square Inch.
P = 20 000 lb.
P = 17 500 lb.
Load over Ties.
P = 20 000 lb.
P = 15 000 lb.
Loads between Ties.
ONE-AND TWO-AXLE LOADS
85-lb. Rail.
6″x 8″x 8′0″ Ties.
6″ Stone Ballast.
Before Tamping

Fig. 53.

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

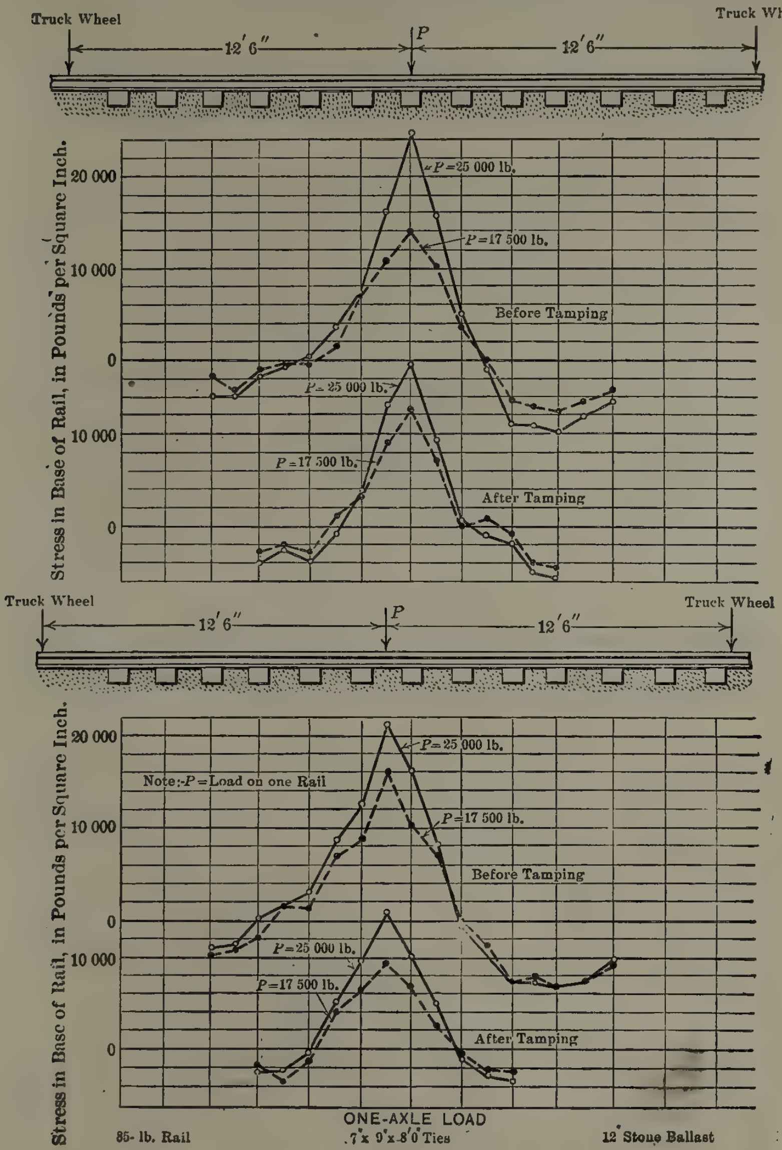


Fig. 54.

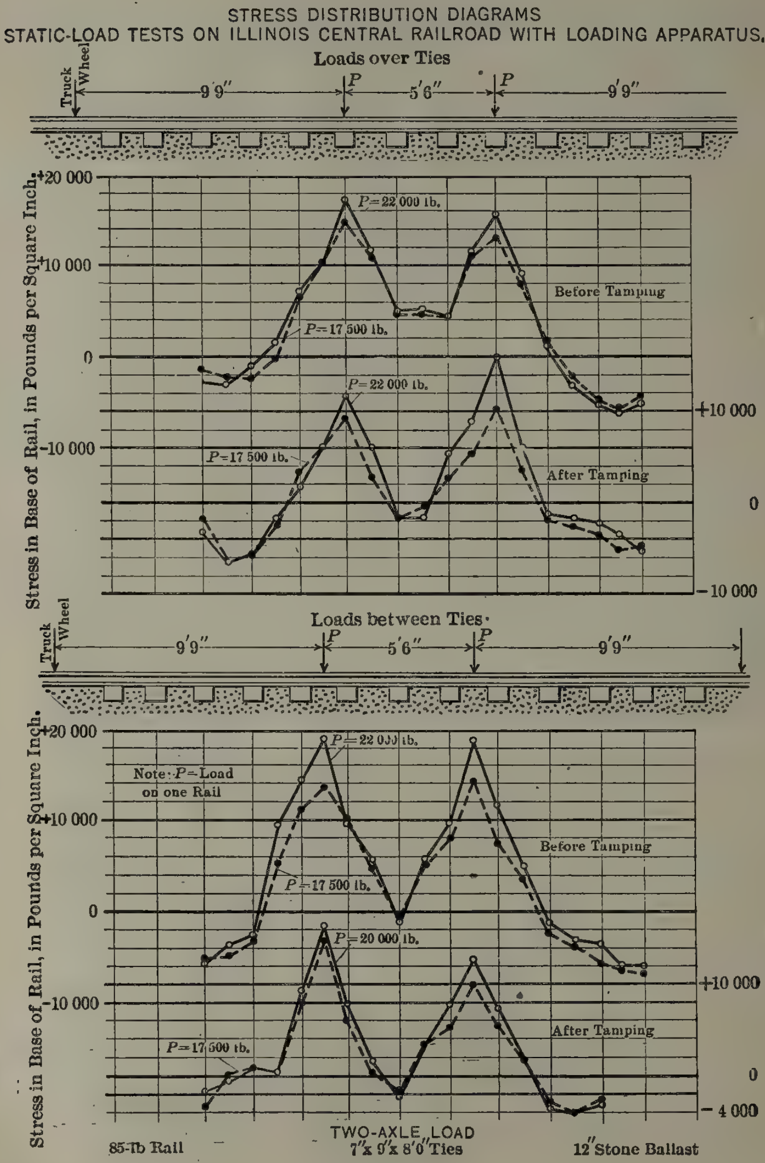
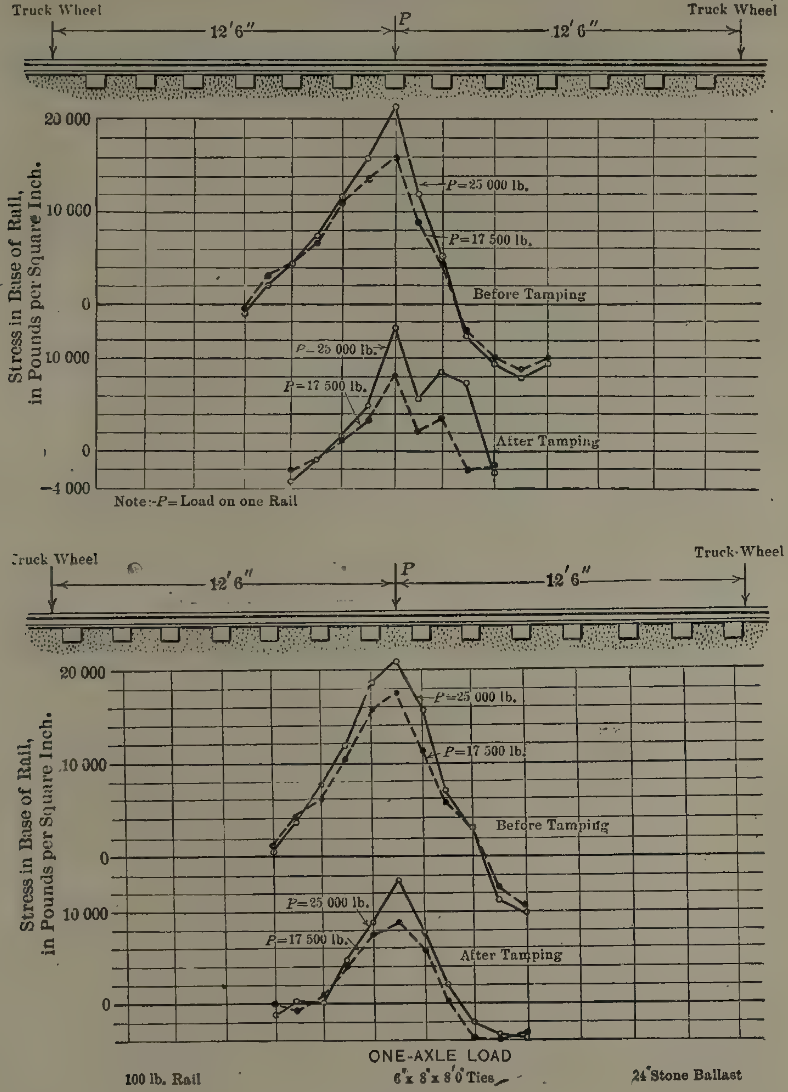

STRESS DISTRIBUTION DIAGRAMS
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.
Loads over Ties
Truck Wheel
9′9″
P
5′6″
P
9′9″
+20 000
+10 000
0
-10 000
Stress in Base of Rail, in Pounds per Square Inch.
P=22 000 lb.
P=17 500 lb.
Before Tamping
P=22 000 lb.
P=17 500 lb.
After Tamping
+10 000
0
-10 000
Loads between Ties
Truck Wheel
9′9″
P
5′6″
P
9′9″
+20 000
+10 000
0
-10 000
Stress in Base of Rail, in Pounds per Square Inch.
Note: P=Load on one Rail
P=22 000 lb.
P=17 500 lb.
Before Tamping
P=20 000 lb.
P=17 500 lb.
After Tamping
+10 000
0
-4 000
85-lb Rail
TWO-AXLE LOAD
7″x 9″x 8′0″ Ties
12″ Stone Ballast

FIG. 55.



STRESS DISTRIBUTION DIAGRAMS.

STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Note:-P= Load on one Rail

ONE-AXLE LOAD

100 lb. Rail 6″x 8″x 8′0″ Ties 24″Stone Ballast

Fig. 56.

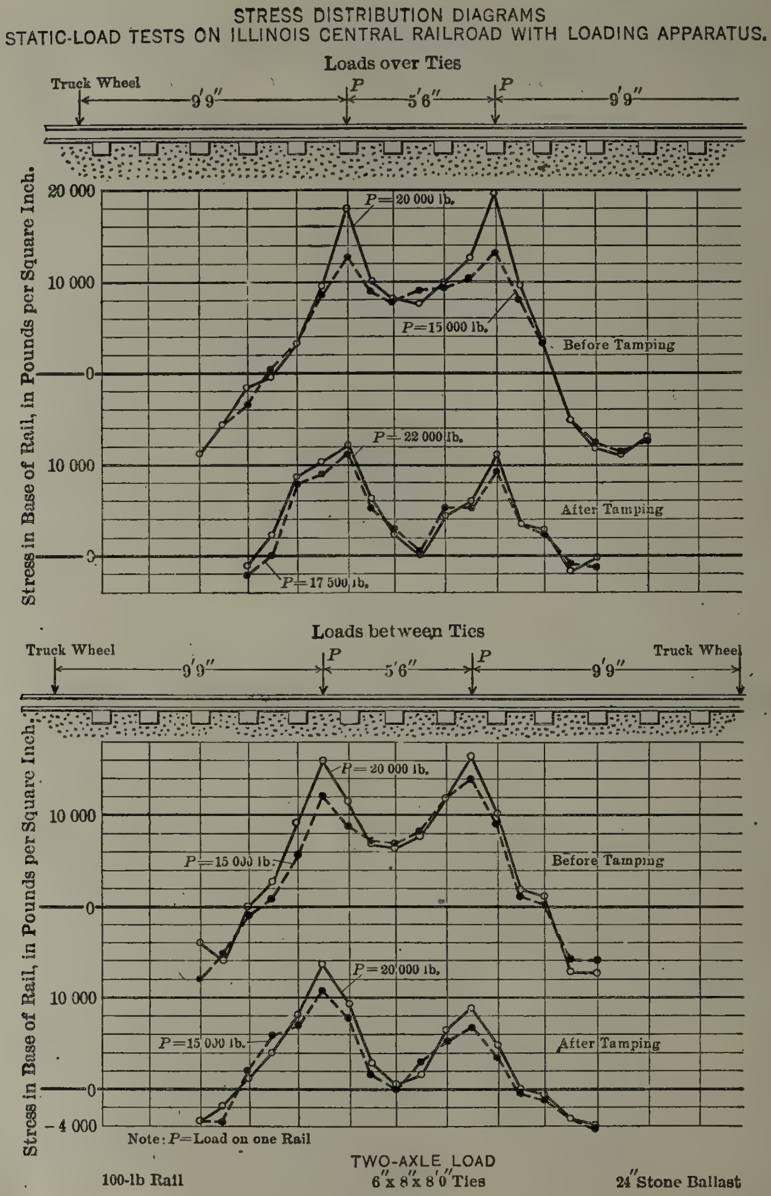
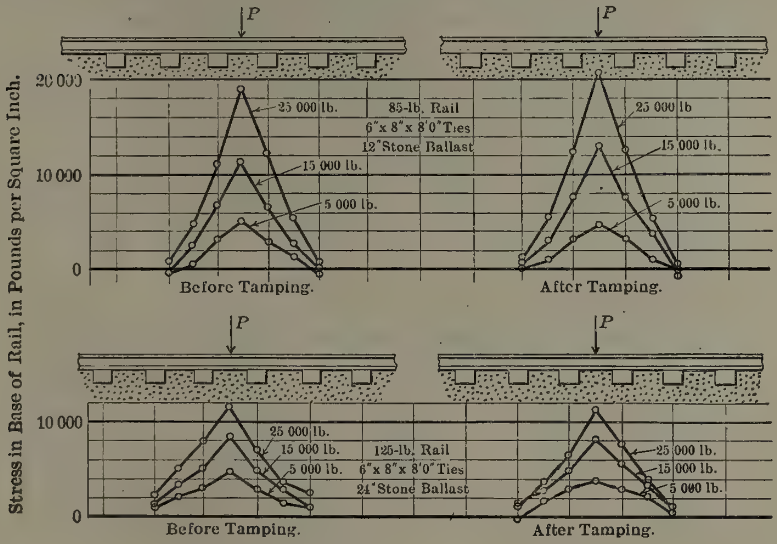

STRESS DISTRIBUTION DIAGRAMS
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.
Loads over Ties
Truck Wheel
9'9"
P
5'6"
P
9'9"
20 000
10 000
0
10 000
0
P=20 000 lb.
P=15 000 lb.
Before Tamping
P=22 000 lb.
P=17 500 lb.
After Tamping
Stress in Base of Rail, in Pounds per Square Inch.
Loads between Ties
Truck Wheel
9'9"
P
5'6"
P
9'9"
Truck Wheel
10 000
0
10 000
0
-4 000
P=20 000 lb.
P=15 000 lb.
Before Tamping
P=20 000 lb.
P=15 000 lb.
After Tamping
Stress in Base of Rail, in Pounds per Square Inch.
Note: P=Load on one Rail
TWO-AXLE LOAD
100-lb Rail
6"x 8"x 8'0" Ties
24" Stone Ballast

FIG. 57.

Little difference is to be found in the rail stress under the load for a load over a tie and for a load midway between ties. The stress is generally somewhat greater for the load between ties, though the difference is smaller than the variations found in different tests.

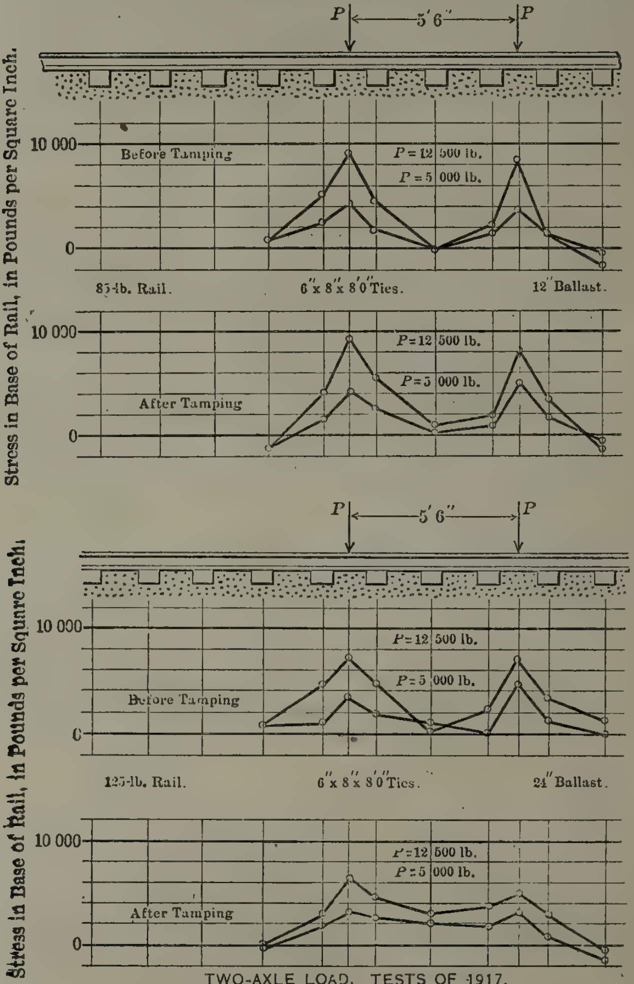
It is seen that the rail stresses differ markedly according to the condition of the track—freshly tamped track giving smaller stresses than track which has been subjected to the action of traffic for a considerable time after receiving a general surfacing. This is found to be true in tests for both the one-axle load and the two-axle load. A comparison of the stresses developed under the two conditions of track may best be made by a study of the load-stress diagrams. In general for freshly tamped track a straight line may be drawn which fits fairly closely the points for the several loads and passes through the origin of co-ordinates. This is the same as saying that the stress developed in the rail is directly proportional to the load applied. For track marked "before tamping" (track which it will be remembered has been described as track in excellent condition), a straight line may be drawn to fit fairly well the points for the several loads, but this line will pass to the right of the origin. For the track "before tamping," then, the stresses appear to increase proportionately to the load, but to the stress found on this assumption must be added a constant stress to obtain the stress which is developed at the given load. It would appear also that the rate of

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.



ONE-AXLE LOAD. TESTS OF 1917.

FIG. 58.

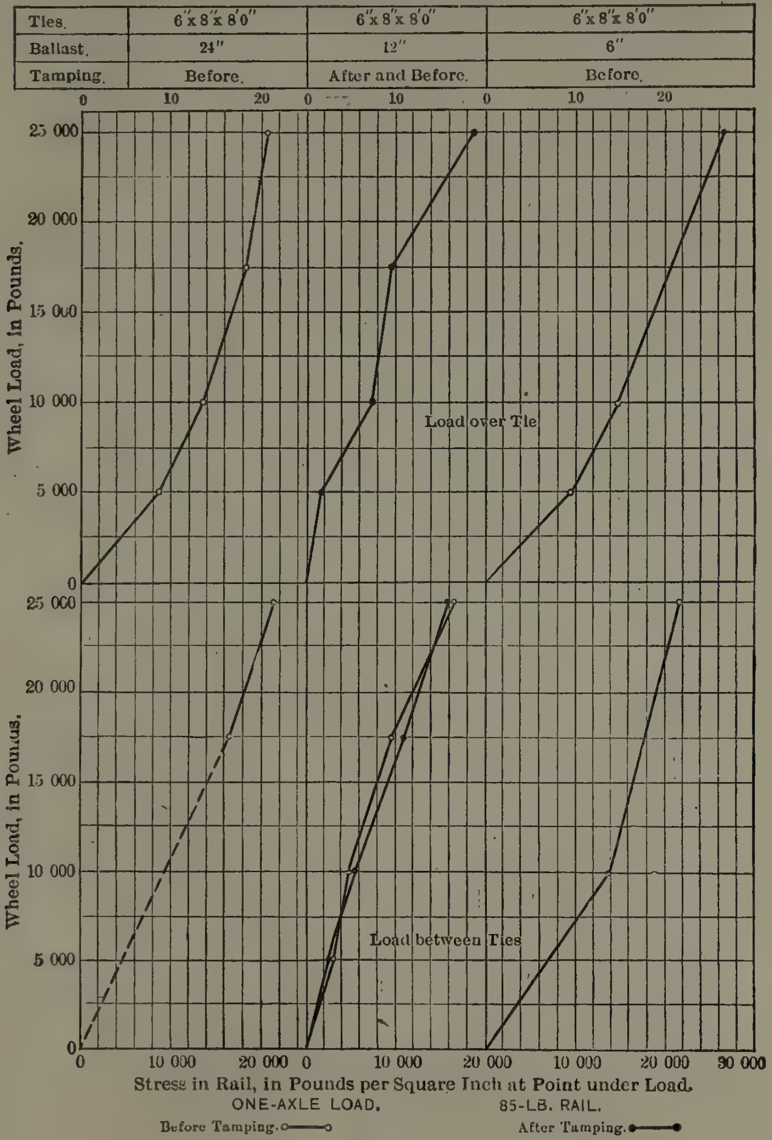


STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH LOADING APPARATUS.

TWO-AXLE LOAD. TESTS OF 1917.
Average of Stresses on two sides of Rail.

FIG. 59.

LOAD-STRESS DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.



Ties.	6″ x 8″ x 8′ 0″	6″ x 8″ x 8′ 0″	6″ x 8″ x 8′ 0″
Ballast.	24″	12″	6″
Tamping.	Before.	After and Before.	Before.

FIG. 60.

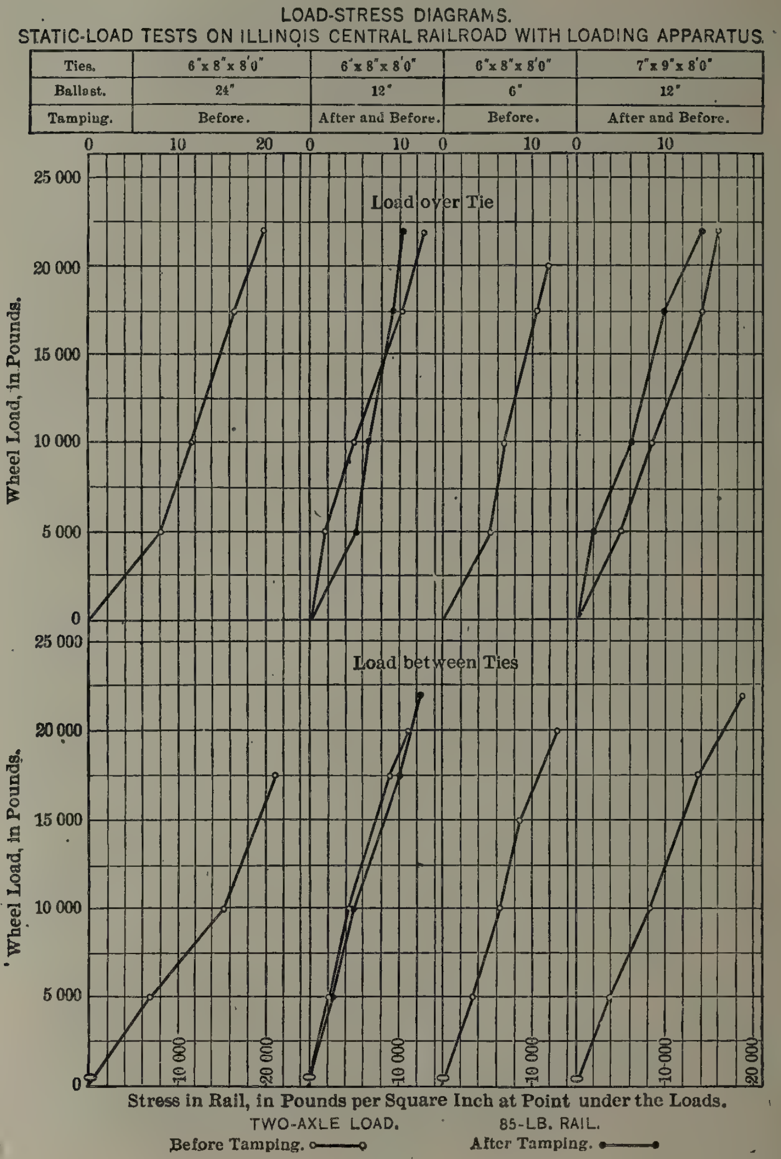

LOAD-STRESS DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.
Ties.
6"x 8"x 8'0"
6"x 8"x 8'0"
6"x 8"x 8'0"
7"x 9"x 8'0"
Ballast.
24"
12"
6"
12"
Tamping.
Before.
After and Before.
Before.
After and Before.
0
10
20
0
10
0
10
0
10
25 000
20 000
15 000
10 000
5 000
0
Load over Tie
Wheel Load, in Pounds.
25 000
20 000
15 000
10 000
5 000
0
Load between Ties
Wheel Load, in Pounds.
10 000
20 000
10 000
10 000
10 000
20 000
Stress in Rail, in Pounds per Square Inch at Point under the Loads.
TWO-AXLE LOAD.
85-LB. RAIL.
Before Tamping.
After Tamping.

FIG. 61.

LOAD-STRESS DIAGRAMS.

STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Ties.	6″x 8″x 8′	6″x 8″x 8′	7″x 9″x 8′
Ballast.	24″	24″	12″
Tamping.	After and Before.	After and Before.	After and Before.

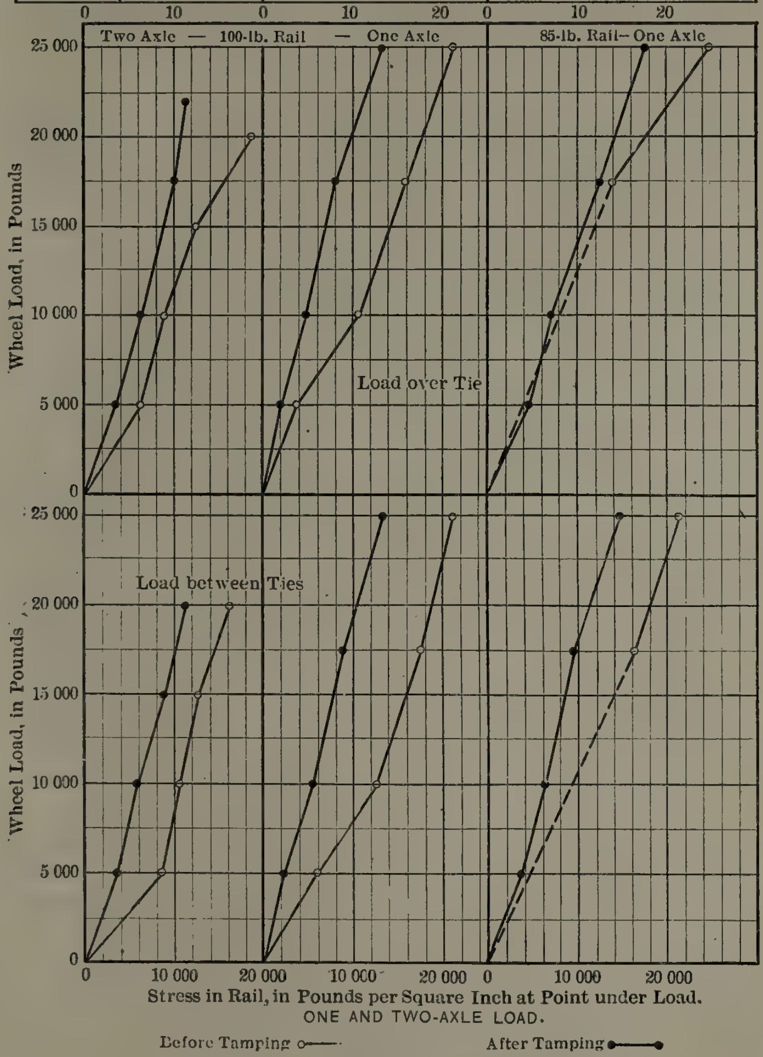


FIG. 62.

increase of stress with increase of load is approximately the same in track "before tamping" as in freshly-tamped track, the lines in the load-stress diagrams being approximately parallel for the two cases. For a rail of 85-lb. section the stress in rail in an untamped track was found to be as much as 6,000 lbs. per sq. in. more than in freshly-tamped track, and this whether the load was 10,000 lbs. or 50,000 lbs. per axle, or whether the stress for the freshly-tamped track was 5,000 lbs. per sq. in. or 20,000 lbs. per sq. in. Tests have not yet been made to determine what the effect would be on track in poor condition.

LOAD-STRESS DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH LOADING APPARATUS.

Rail.	85 lb.	125 lb.	85 lb.	125 lb.
Ties.	6″x 8″x 8′	6″x 8″x 8′	6″x 8″x 8′	6″x 8″x 8′
Ballast.	12″	24″	12″	24″

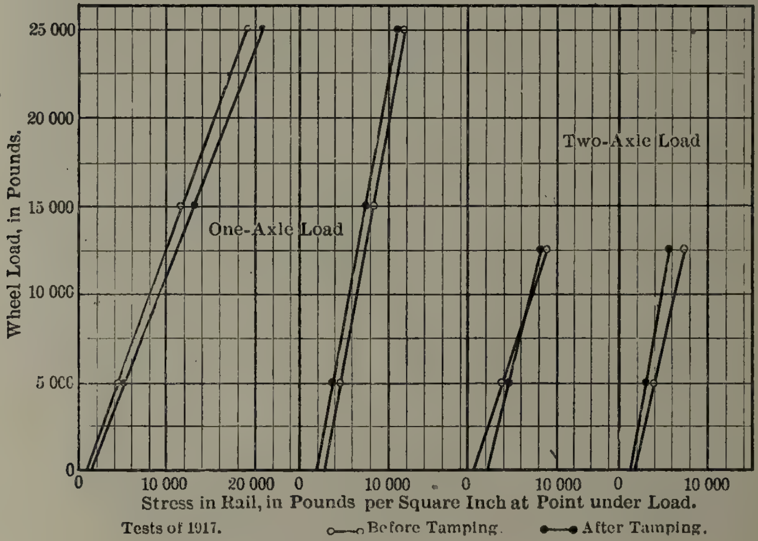


FIG. 63.

The stress-distribution diagrams give a very good indication of the way the stresses vary along the rail at points away from the wheel load and also the way the moments change from positive to negative. It will be seen that the shape of the curves and the distribution of stresses along the rail are very similar to the distribution found by the analysis heretofore given as illustrated in Fig. 9. In a few cases the shape of the curves at points away from the load does not accord with analytical considerations, the curvature being in the wrong direction, but this may have been due to an undetermined factor which entered into the results when the strain measurement was made on only one side of the rail..

It cannot be expected that the distance from the load point to the point of zero-stress in the rail can be determined with accuracy from the stress distribution diagram, since the effect of the release of load on the truck wheels may extend to the point of zero-stress and since the slope of the stress-distribution curve near the point of inflection is relatively flat. Because of these facts and because slight variations of track conditions will greatly affect the stress distribution diagram in this vicinity, it is seen that the point of zero-stress cannot be accurately and definitely determined by tests of this nature. Although values could not be definitely determined for either, the distance from the load point to the point of zero-deformation, taken from the depression profiles, is found to be approximately three times the distance from the load point to the point of zero-deformation taken from the stress distribution diagrams, the data for both being taken from the same tests on freshly-tamped track—thus agreeing with the results found by the analysis already given.

The stress distribution diagrams and the load-stress diagrams show that for the same wheel load the stress in the rail under the load is less for the two-axle load than for a one-axle load. It is evident that for the load spacing used the effect of a second load is to produce a negative moment in the rail in the vicinity of the other load point and thus this acts to decrease the stress in the rail at each load point. To show the effect of a combination of two one-axle loads a composite diagram has been made up in Fig. 64. The broken line represents the resultant stresses found by taking the stresses observed in a typical one-axle load test and then finding composite values by taking the algebraic sum of the stresses for two such loads spaced 66 in. apart. It is seen that this composite line does not differ markedly from the full line which represents experimental values from tests with two-axle load. In Fig. 64 is also given by a dotted line a composite diagram for two-axle load obtained from the analysis outlined in 6, Combination of Wheel Loads. This also is in agreement with the results obtained in the tests.

To bring out the fact that relations exist in the stresses and moments along the rail which vary with the spacing of the wheels and the properties of the track, there are given in Fig. 65 three composite bending moment distribution diagrams for two-axle loads which were made up by means of the analysis heretofore given. The upper one (a) is based upon a value of x_1 (the distance from a single wheel load to the point of zero bending moment in the rail) equal to ⅔ of the distance between the loads; the middle one (b) upon a value of x_1 equal to ½, and the lower one (c) upon a value of x_1 equal to ⅓ of the distance between loads. The value which may be expected to apply to track in any case will depend upon (1) the spacing of the loads, (2) the rail section used and (3) the stiffness of the rail-support.

In the tests with two-axle load on rail of 85-lb. section the stress distribution diagrams for freshly-tamped track generally show a nega-

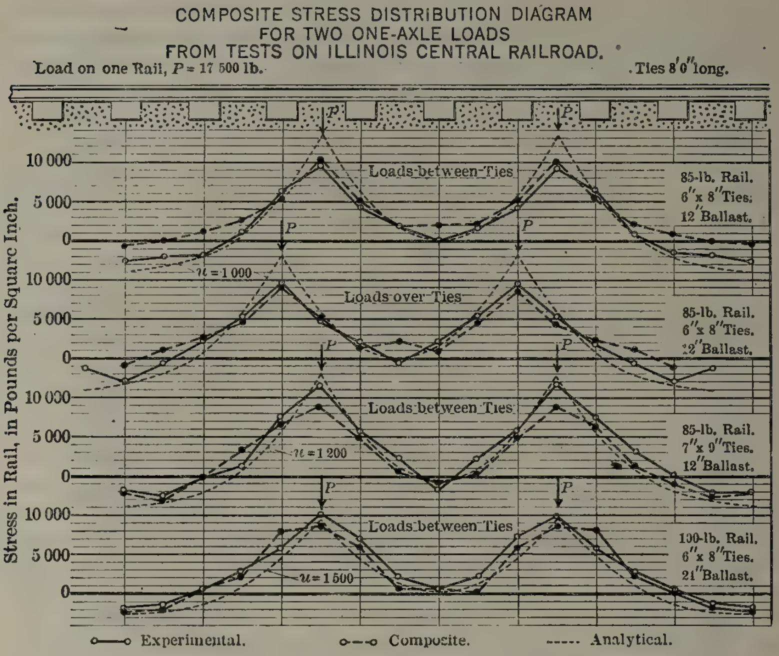

COMPOSITE STRESS DISTRIBUTION DIAGRAM FOR TWO ONE-AXLE LOADS FROM TESTS ON ILLINOIS CENTRAL RAILROAD.

FIG. 64.

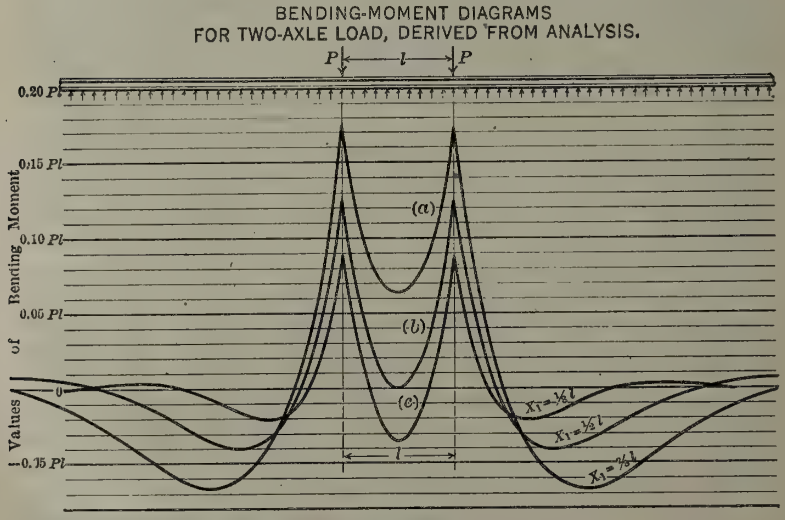

BENDING-MOMENT DIAGRAMS FOR TWO-AXLE LOAD, DERIVED FROM ANALYSIS.

FIG. 65.

tive moment at a point midway between loads. The form of the diagram corresponds to the form of diagram obtained by using in the analysis a value of x_1 (the distance from a single wheel load to a point of zero bending moment) of about 28 in. For rail of 85-lb. section in track not freshly tamped the moment at a point midway between loads, as shown by the diagrams, runs from zero to a positive moment of .25 of the moment at the load point, and the stress at the load points is greater than was found with freshly-tamped track. For those tests which give a moment of zero at the midway point it appears from the load-stress diagrams that the track was in much better surface condition than for the tests which give the higher moment at the midway point. For the highest loads used in these tests it would appear from the stress distribution diagrams as if the axis of zero-stress in the diagrams for freshly-tamped track had been lowered from 5000 lbs. to 7000 lbs. per sq. in., the stress distribution diagrams for track not in freshly-tamped condition giving about the same results as this changed diagram.

For the rail of 100-lb. section the stress distribution diagrams for freshly-tamped track show a zero moment at a point midway between loads. This form of the diagram corresponds in the analysis to a value of the distance from a single wheel load to a point of zero bending moment, x_1, of about 33 in., one-half of the distance between points of applied load. In track not freshly tamped the moment at the point midway between loads is found to be positive and equal to about four-tenths of the moment at the wheel load, and the stress under the wheel load is greater than for track freshly tamped. For the higher loads the same comment may be made, the diagrams for track not freshly tamped bearing a resemblance to those for freshly-tamped track with the axis of zero stress moved downward about 6000 lbs. per sq. in.

43. *Stresses in Rail; Static Load Tests With Mikado Locomotive.*—In Figs. 66 and 67 are given stress distribution diagrams for static load tests with the Mikado locomotive on rail of 85-lb. section and 100-lb. section on the test sections of track on the Illinois Central Railroad north of Champaign. For the 85-lb. section tests were made on three depths of ballast and two sizes of ties; for the 100-lb. section tests were made on one depth of ballast. In all these tests the track was in a freshly-tamped condition.

The stress distribution diagrams give a very good indication of the variation in stresses along the rail with respect to the position of the wheel loads. The maximum stresses in the rail are located directly under the wheels, positive moment being developed at these points. Negative moments occur at points between the wheels. The stress under the inner two drivers is generally less than that under the outer drivers, and that under the front driver is generally somewhat greater than that under the rear driver. In the upper diagram of Fig. 67 the stress under the front driver is quite low. The values plotted on this diagram are the average of two tests at the same spot, the locomotive

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

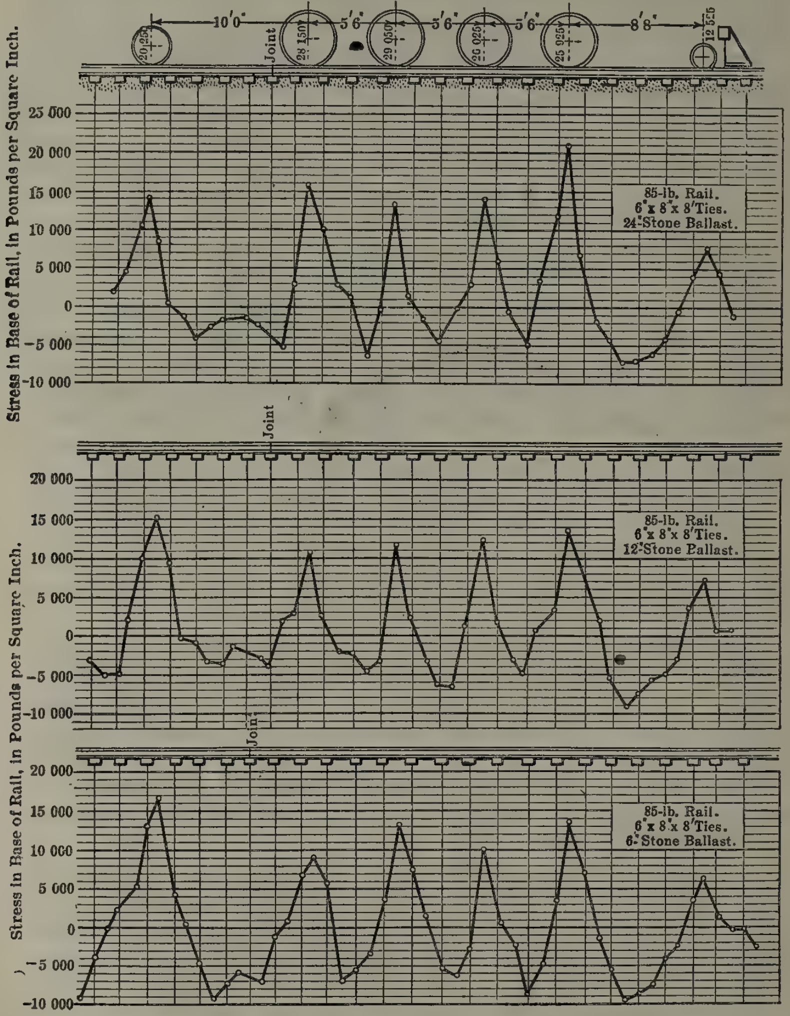
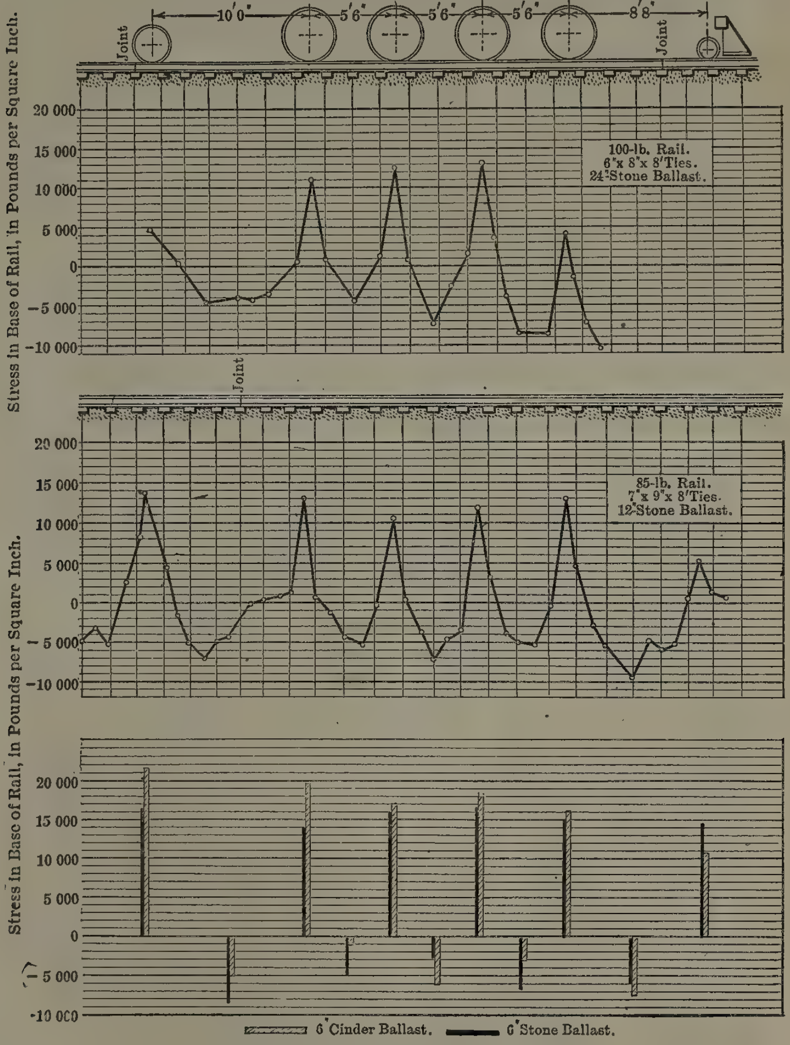


FIG. 66.

STRESS DISTRIBUTION DIAGRAMS.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.



PRELIMINARY TEST.

FIG. 67.

used in the second not being the one used in the first test. The results of the two tests are concordant. Another peculiarity of this diagram is that the stresses under the inner drivers are higher than would be expected. It will be seen that the highest negative moment in all these tests is between the front truck wheel and the front driver. The stress here ranges from 40 per cent. to 60 per cent. of that developed under the front driver. The stress under the trailer is nearly as much as that under the outer drivers, although the load on the trailer is only about three-quarters as much as that on a driver. Comparing these stress distribution diagrams with Fig. 6, which was obtained from the analysis of track action, it is seen that the general form of the curves and the way in which the stresses vary with respect to the position of the wheel loads are quite similar.

In these static-load tests strain measurements were made on the outer edge of the base of the rail only. In the moving-load tests, made after the static-load tests were completed, it developed that there were considerable differences between the stresses on the two sides of the rail. A static test was then made to find whether a similar condition obtained when the locomotive was stationary. These tests showed similar differences in the magnitude of the stresses on the two sides of the rail. The values found for the static-load tests with the locomotive, given in Figs. 66 and 67, then may not be expected to represent accurately the average stress in the base of the rail. The amount of difference between the stress on the outside of the rail and the average stress on the two sides, as will be shown later, has been found to vary in different tests. However, the results of the strain gage measurements on only one side of the rail are of interest and value in a number of ways, and they may be considered to show in a general way the distribution of stress along the rail under the given loading.

The tests on rail of 100-lb. section gave lower stresses, as might be expected, but the general distribution of stresses along the rail was much the same. The effect of the increased section of rail upon the bending moment developed will be discussed later.

In Fig. 67 is also given the stress distribution diagram from a preliminary test on a piece of track with 85-lb. rail section and about 6 in. of stone ballast, which had not been specially prepared for the test. This track had not been tamped recently, but was apparently in good condition. Although as stated in 38, Depression of Track; Static-Load Test With Mikado Locomotive, the track depressions were greater than for the prepared test track, it is not apparent that the rail stresses differed much from those found on the prepared test track, but there is much more variation in stress for different settings of the locomotive. In Fig. 67 is also given the stress distribution diagram for a preliminary test of track with cinder ballast about 6 in. deep and having 85-lb. rail. The stresses in rail for this track are larger than those for track on stone ballast. The track had not been tamped recently, and it is not known what part of the increase was due to the condition of the track.

44. *Stresses in Rail; Static Load Tests With Switching Locomotive.*—Fig. 68 gives the stress distribution diagram for static loading with a switching locomotive, as found in an early preliminary test on the Illinois Central Railroad. The measurements are not entirely trustworthy, but both the tests on stone ballast and on cinder ballast with a rail of 85-lb. section gave a stress under the middle driver of about 80 per cent. of that under the front driver. One stress distribution diagram given in Fig. 68 is from an early test on track on a branch line having worn rail of 56-lb. section, and cinder ballast. The stress under the front driver is about 40,000 lbs. per sq. in., and that under the middle driver about 35,000 lbs. per sq. in. In this test the measurements were made over a length of track of a few tie spaces, the locomotive being run forward from time to time so that each driver was successively spotted over the same gage line. The stresses may therefore not be the same as though taken on the rail over the full length of the locomotive at a single setting.

45. *Stresses in Rail; Moving Load Tests.*—As has been stated in the description of the procedure of tests, in the moving-load tests four or five runs were generally made at each of the several speeds, the locomotive not working steam while running over the test section. As shown in Fig. 31, three instruments generally were placed on one rail at points between ties and at tie spaces adjacent to each other. The fourth instrument was placed on the other rail opposite the middle one of the three instruments. As the position of the locomotive driver was always such that the counterweight of the front driver was at its lowest point when this driver passed over the middle instrument of the three, the position of the counterweight of the second or other driver when this driver passed a given instrument was different from that of the first driver when its record was made. It is seen, then, that the tests were made in such a way as to give the same effect of counterweight in each run, but that the several drivers had different positions of counterweight when passing an instrument and making a record.

In all the moving-load tests here reported, measurement of strain was made on the two sides of the rail by each instrument, and the average stress for the two sides of the rail is here reported. In some cases the record on one side or the other proved defective and in these cases the good records were used. As there were four instruments and generally four or five runs at each speed for each set-up and three set-ups at adjacent locations, the value of the stress reported for a given driver at a given speed, and for a given test section, is generally the average of about a hundred records, and thus may be considered to be representative. It should be repeated that the stresses reported are the fiber stresses in the base of the rail at the midpoint of the gage

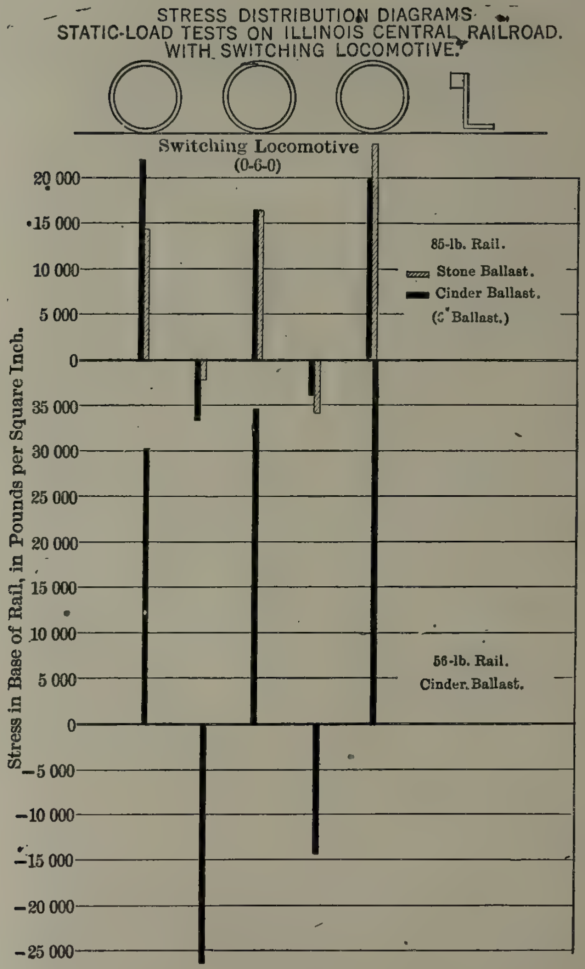

STRESS DISTRIBUTION DIAGRAMS
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD.
WITH SWITCHING LOCOMOTIVE.
Switching Locomotive
(0-6-0)
20 000
15 000
10 000
5 000
0
35 000
30 000
25 000
20 000
15 000
10 000
5 000
0
−5 000
−10 000
−15 000
−20 000
−25 000
Stress in Base of Rail, in Pounds per Square Inch.
85-lb. Rail.
▨ Stone Ballast.
■ Cinder Ballast.
(6" Ballast.)
56-lb. Rail.
Cinder Ballast.

FIG. 68.

line as reduced from the measured strains. As the instruments were placed between ties, the measurement of stress for positive moment occurred with the driver between ties. The measurement of maximum stress for a negative moment depended upon the wheel spacing, occurring when the adjacent drivers of the Mikado locomotive were over ties and when the drivers of the Atlantic locomotive were between ties.

In Figs. 69 to 91 the data obtained in the tests on the Illinois Central Railroad, north of Champaign, are presented in graphical form for the three types of locomotive used. For each speed the stress under each wheel has been plotted and also the stress at the point of maximum negative moment between wheels. The scale of the stress is to be taken as beginning under the wheel for the positive moment stress and at the point between wheels indicated for the negative moment stress. Straight lines have been drawn to give the general trend of the stresses. The type of locomotive and descriptive items concerning the track and its condition are noted on the diagrams. The stresses indicated by the straight lines on these diagrams were considered to be representative of the average stresses for the given conditions. The averages of all of the values given by the straight lines have been taken for two speeds and have been plotted for both positive and negative moments in Figs. 92 to 97. As has already been noted, the type of instrument used in the 1915 tests is less accurate than the newer instrument and gives values which are smaller than the true values. For this reason, the 1916 results will be used for comparisons wherever possible.

46. *Stresses in Rail; Tests on Delaware, Lackawanna & Western Railroad.*—In Figs. 98 to 101 are given speed-stress diagrams obtained from the data of the tests on the Delaware, Lackawanna & Western Railroad, near Dover, N. J., for the four locomotives used. The values given by the straight lines on these diagrams have been taken for two speeds and have been plotted for both positive and negative moments in Figs. 102 to 105.

47. *Modulus of Elasticity of Rail-support.*—The term modulus of elasticity of rail-support has already been defined as the pressure per unit of length of each rail required to depress the track one unit. It measures the vertical stiffness of the support of the rail. The magnitude of the modulus of elasticity of rail-support is dependent upon a number of elements such as the compressibility of the tie and its flexural stiffness, the breadth and length of the tie, the tie spacing, the character of the bearing of the tie on the ballast, the thickness, solidification and stiffness of the ballast, the nature of the roadway and the way in which the pressures are distributed over it. As the stresses developed in the rail and the division of load among tie reactions are directly affected by the magnitude of the modulus of elasticity of rail-support, this modulus may serve as one criterion of the quality of track. It will therefore be of interest to learn what range of values of the modulus of elasticity of rail-support may be expected for various kinds and conditions of track.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

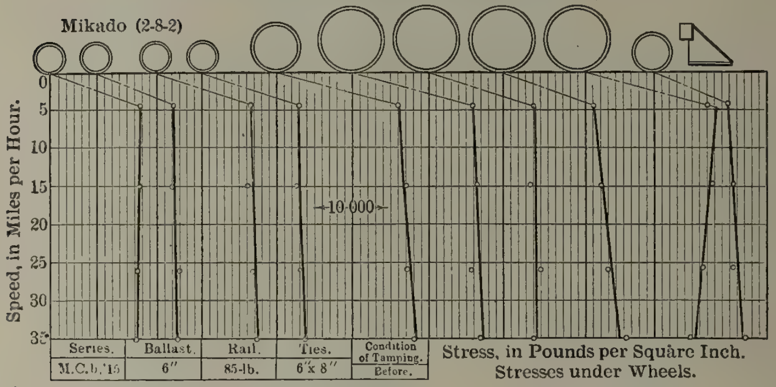


FIG. 69-a.

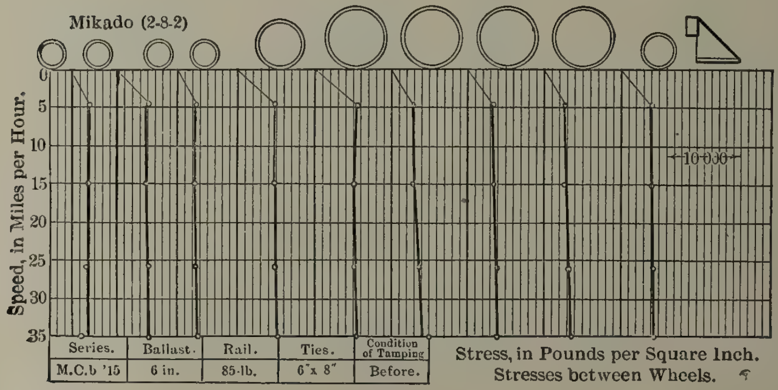


FIG. 69-b.

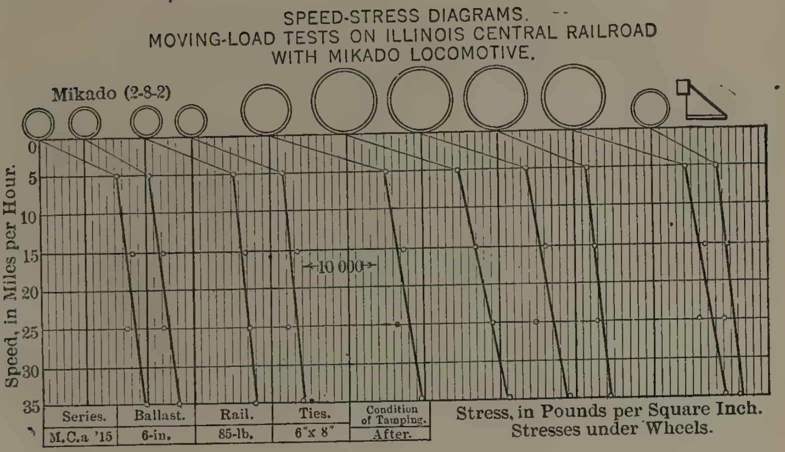

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

FIG. 70-a.

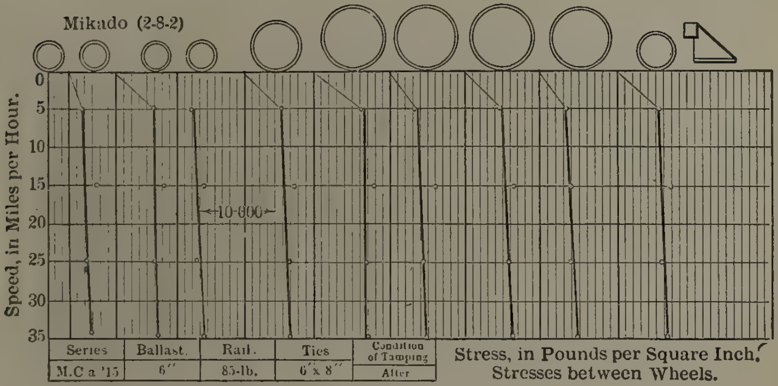


FIG. 70-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

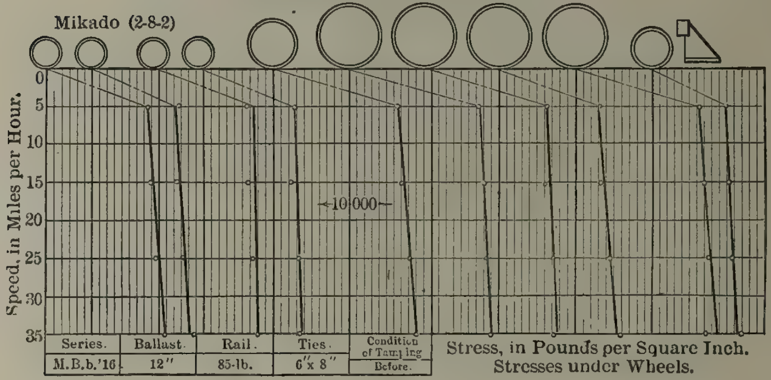


FIG. 71-a.

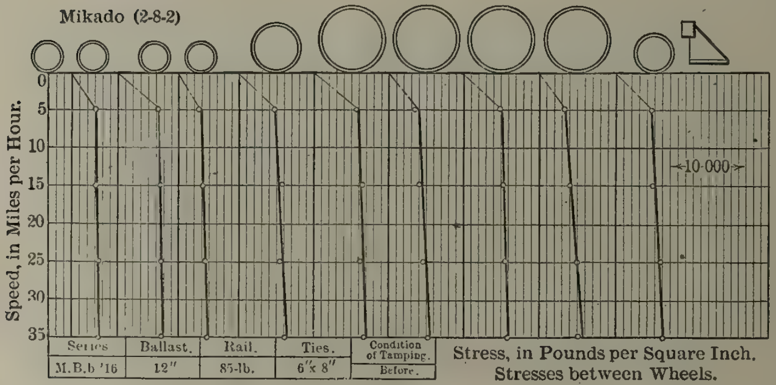


FIG. 71-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

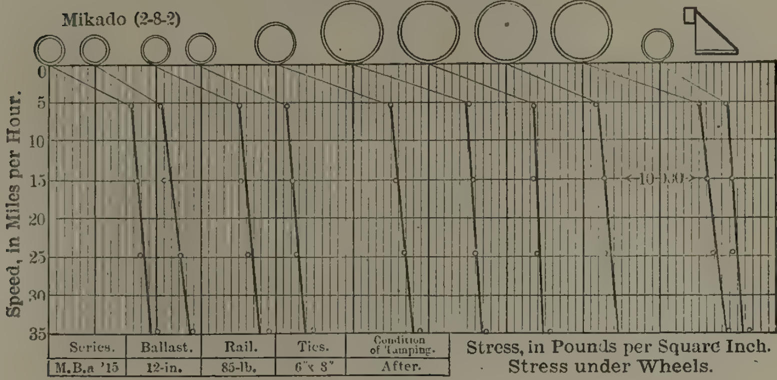


Fig. 72-a.

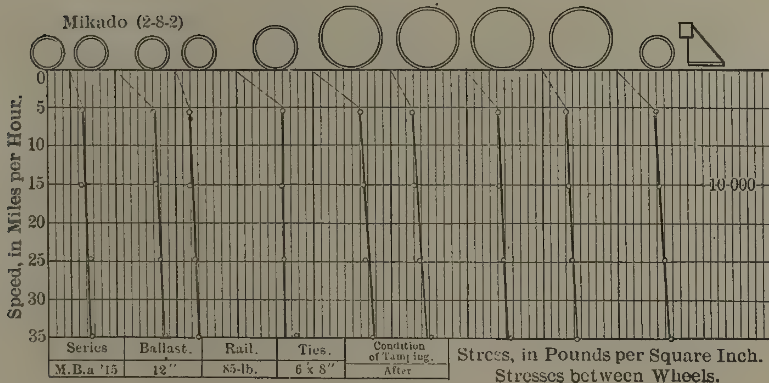


Fig. 72-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

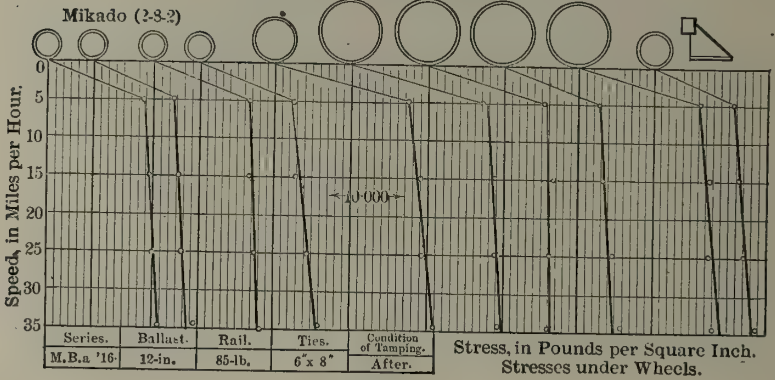


FIG. 73-a.

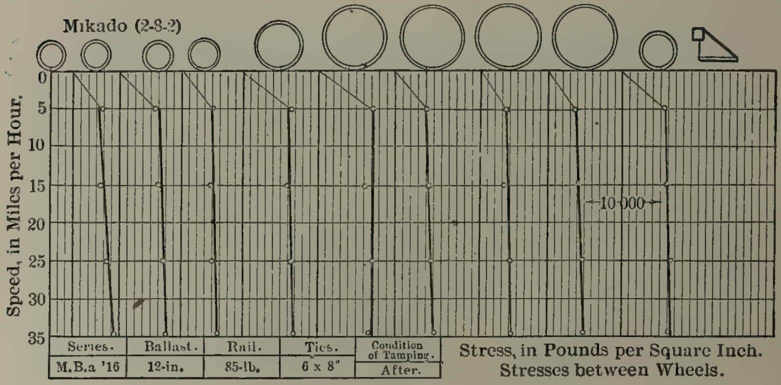


FIG. 73-b.

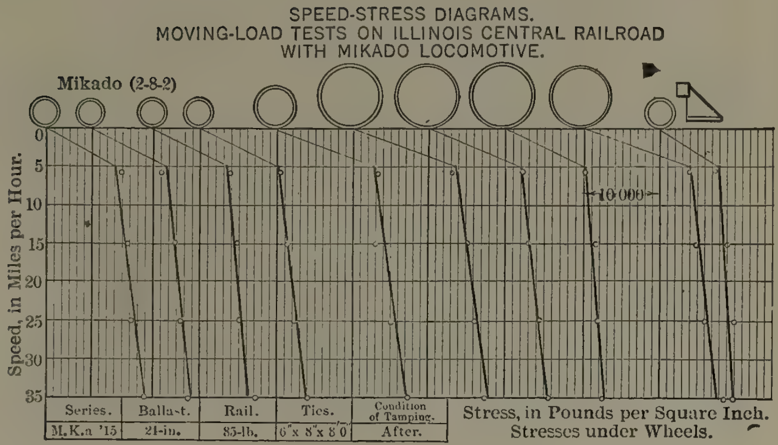


FIG. 74-a.

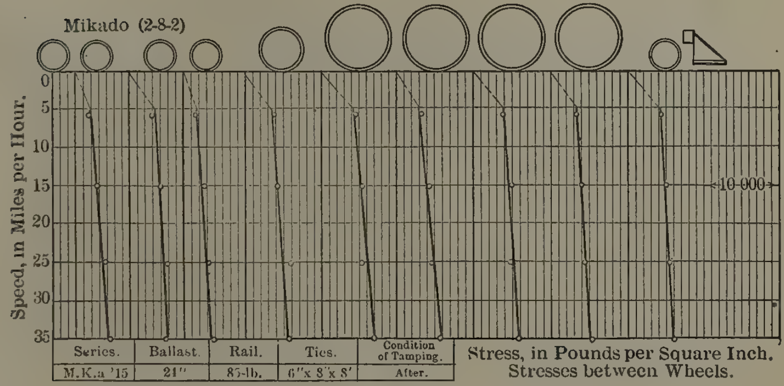


FIG. 74-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

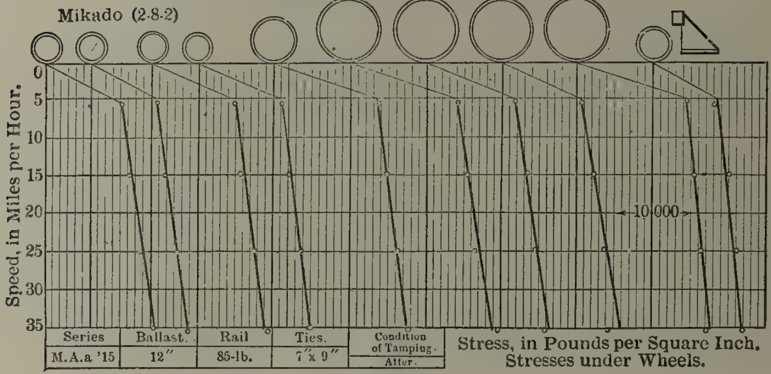


Fig. 75-a.

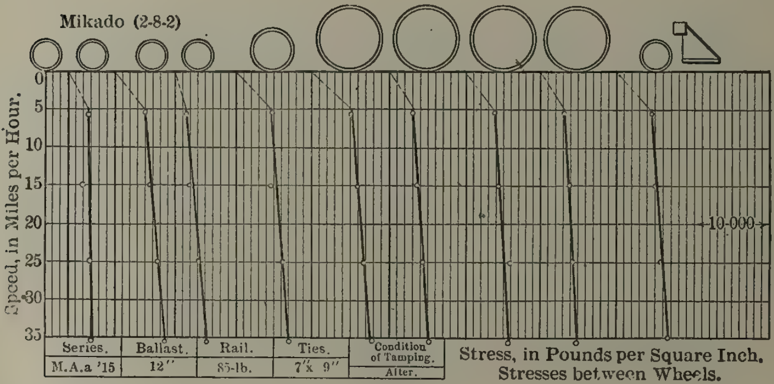


Fig. 75-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

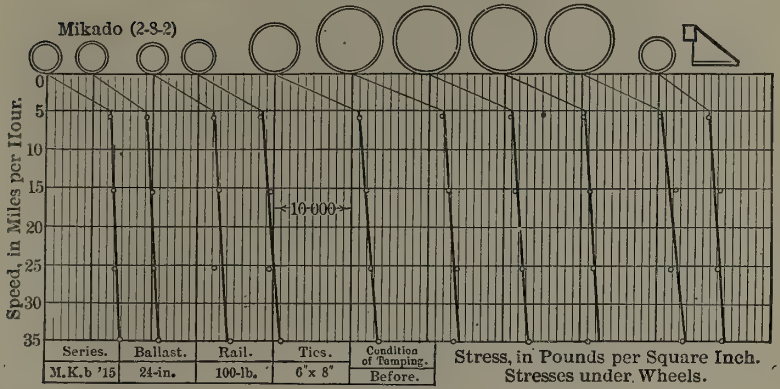


FIG. 76-a.

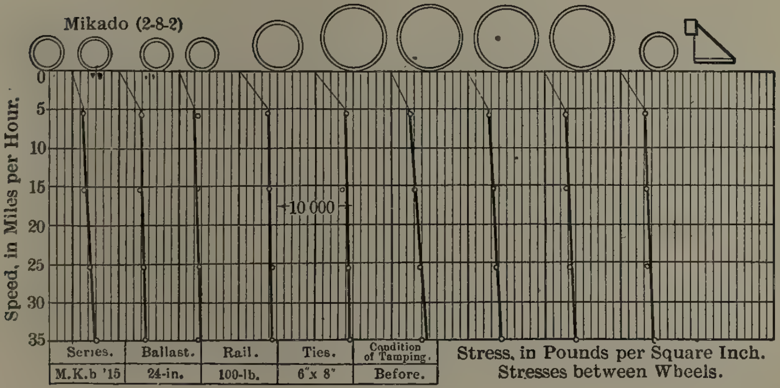


FIG. 76-b.

SPEED-STRESS DIAGRAMS.

MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

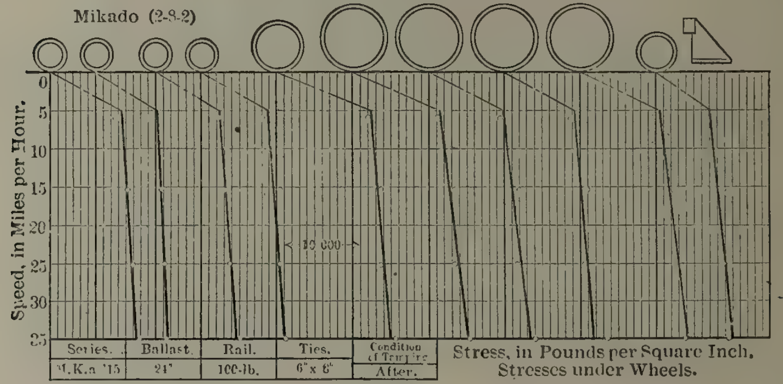


FIG. 77-a.

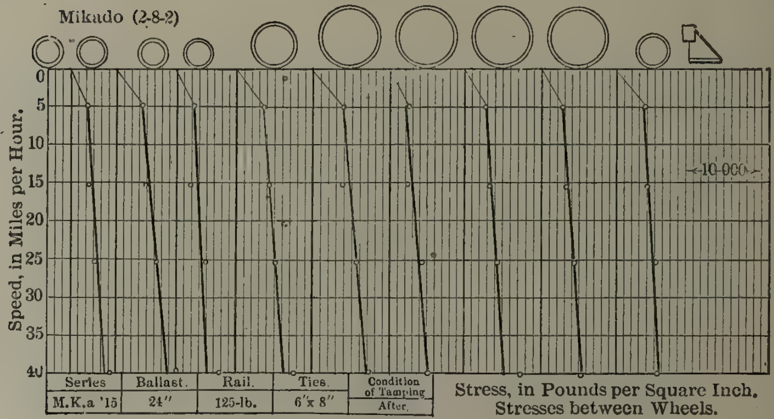


FIG. 77-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

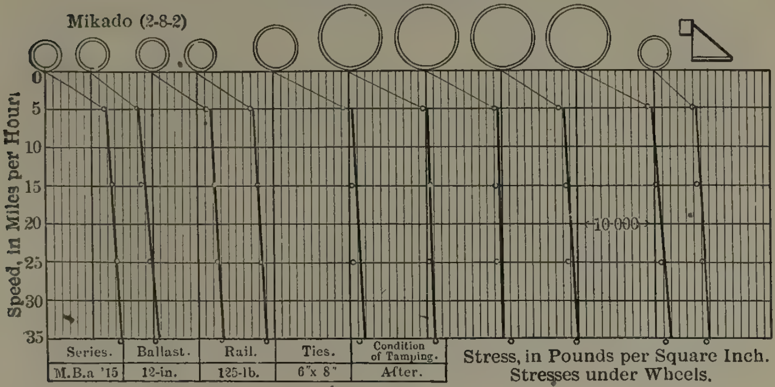


FIG. 78-a.

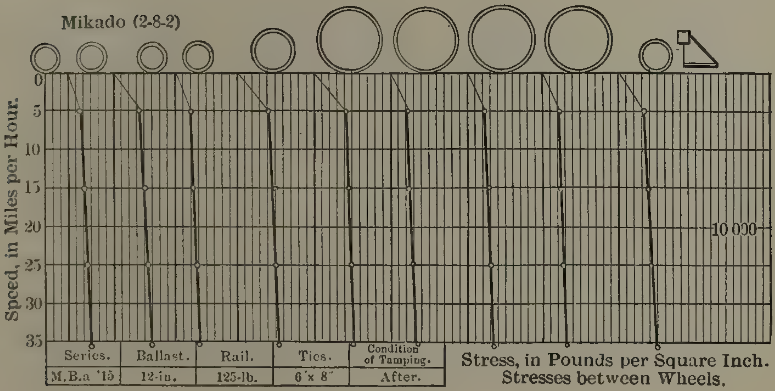
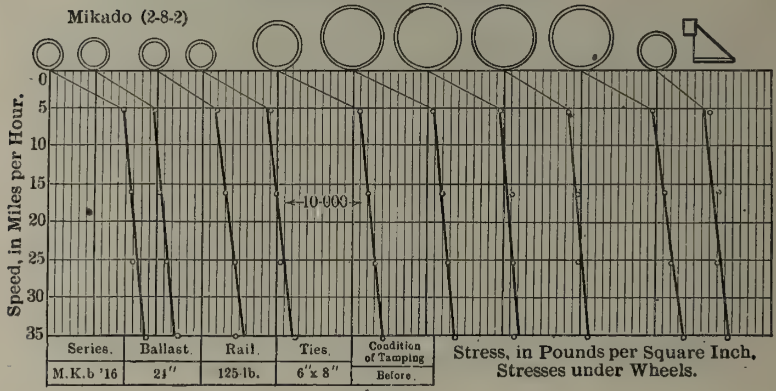


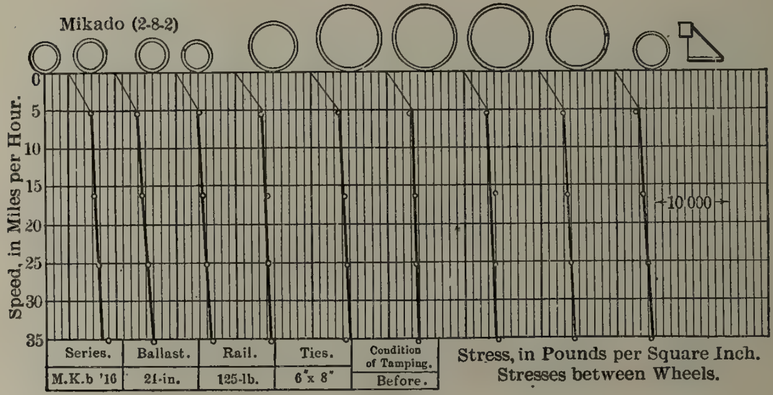
FIG. 78-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping
M.K.b '16	21"	125-lb.	6"x 8"	Before.

FIG. 79-a.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
M.K.b '16	21-in.	125-lb.	6"x 8"	Before.

FIG. 79-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

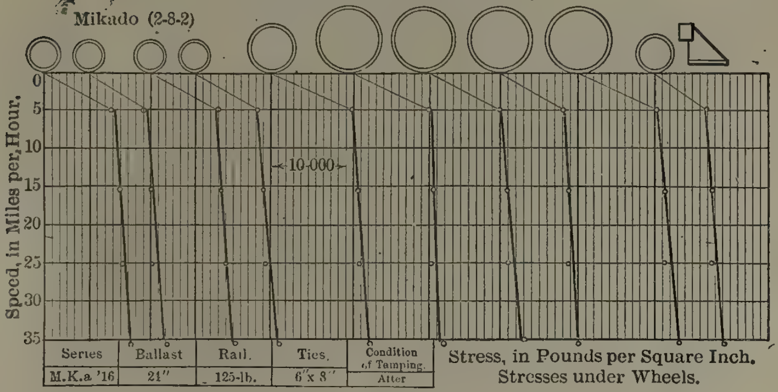


FIG. 80-a.

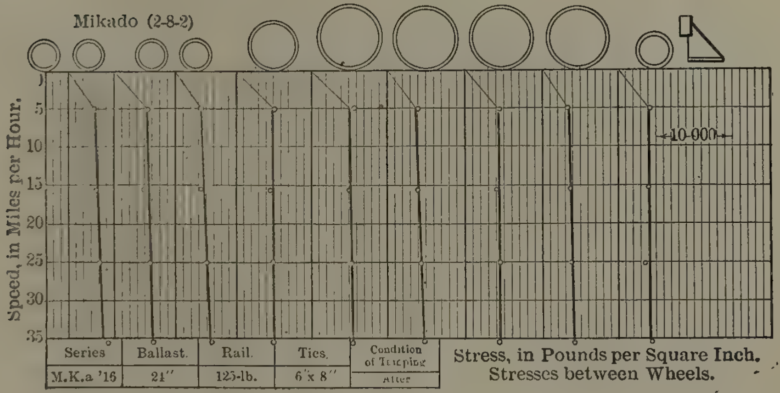


FIG. 80-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

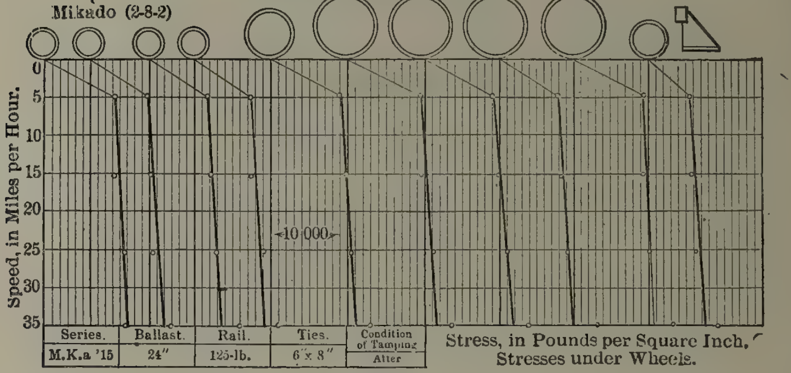


FIG. 81-a.

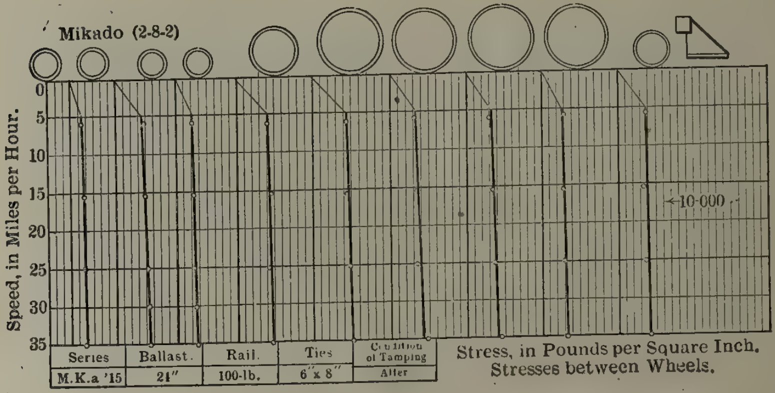
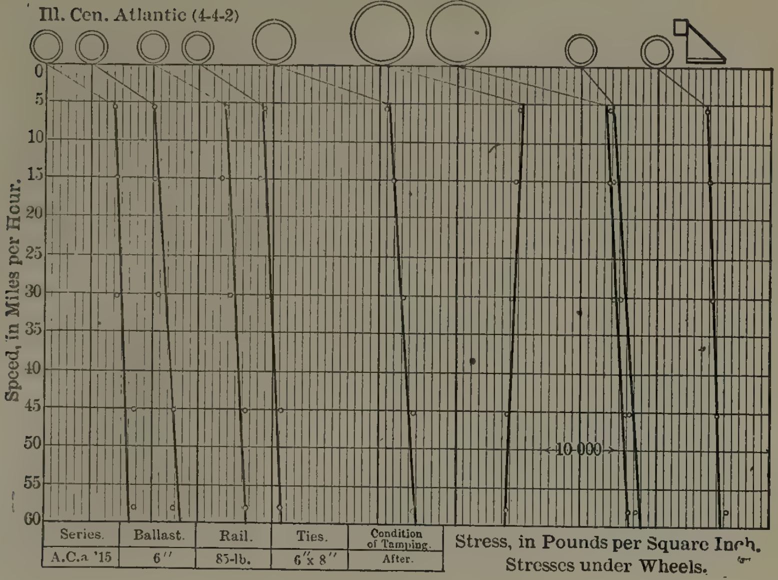


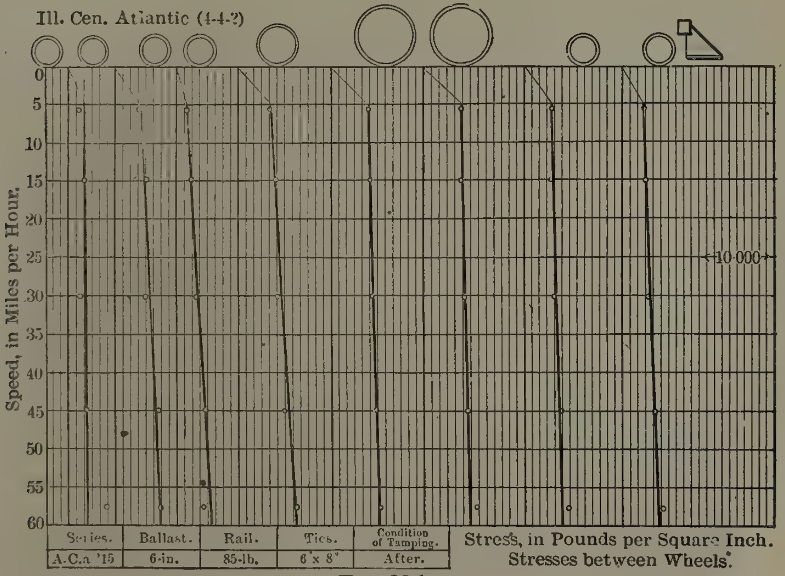
FIG. 81-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
A.C.a '15	6″	85-lb.	6″x 8″	After.

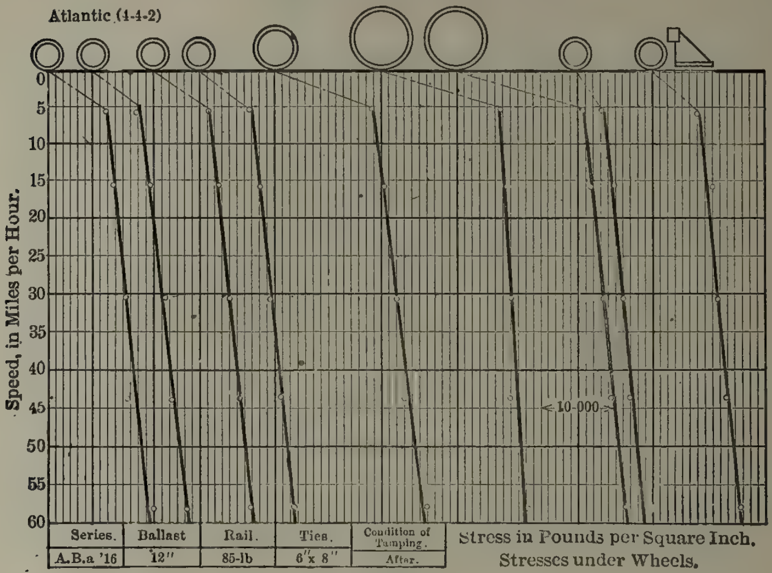
FIG. 82-a.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
A.C.a '15	6-in.	85-lb.	6″x 8″	After.

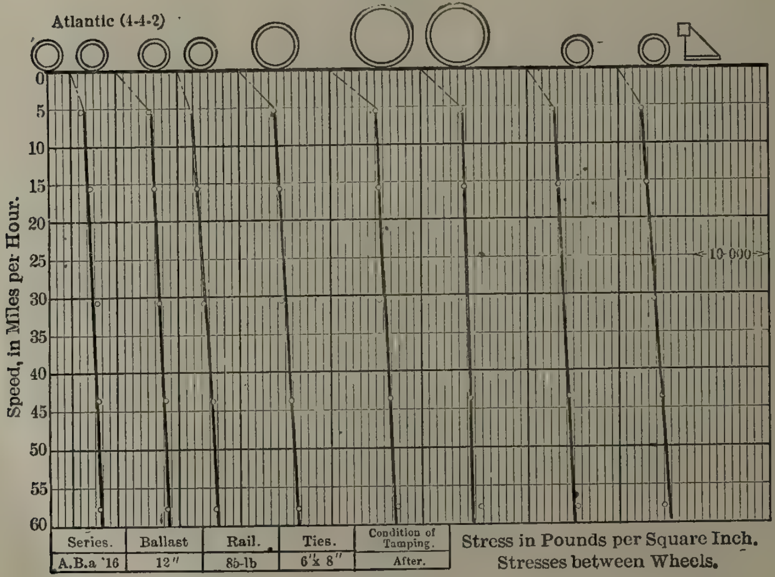
FIG. 82-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.



Stress in Pounds per Square Inch.
Stresses under Wheels.

FIG. 83-a.



Stress in Pounds per Square Inch.
Stresses between Wheels.

FIG. 83-b.

SPEED-STRESS DIAGRAMS
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.

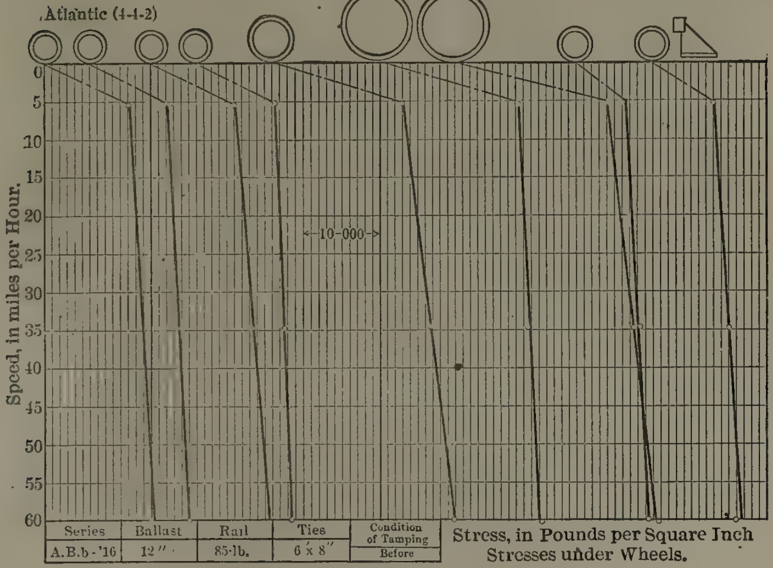


Fig. 84-a.

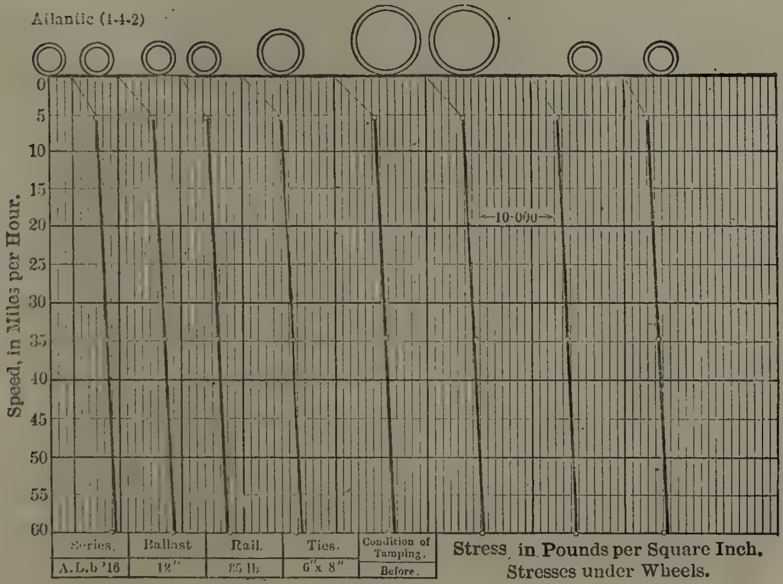
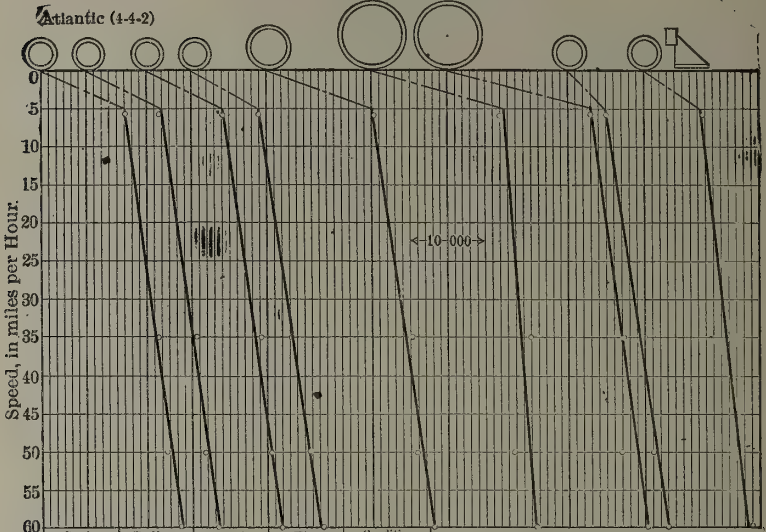


Fig. 84-b.

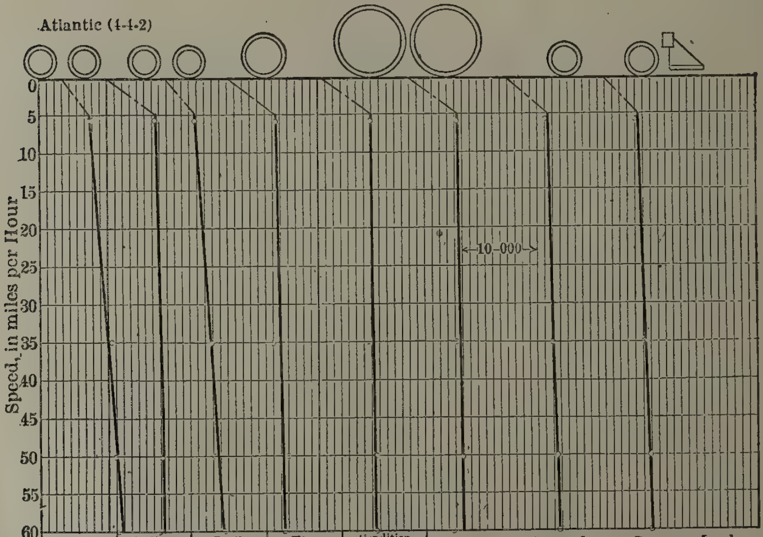
SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.



Series	Ballast	Rail	Ties	Condition of Tamping
A.B.a-'16	12"	85-lb.	6"x 8"	After

Stress, in Pounds per Square Inch.
Stresses under Wheels.

FIG. 85-a.



Series	Ballast	Rail	Ties	Condition of Tamping
A.B.a-'16	12"	85-lb.	6"x 8"	After

Stress, in Pounds per Square Inch.
Stresses between Wheels.

FIG. 85-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.

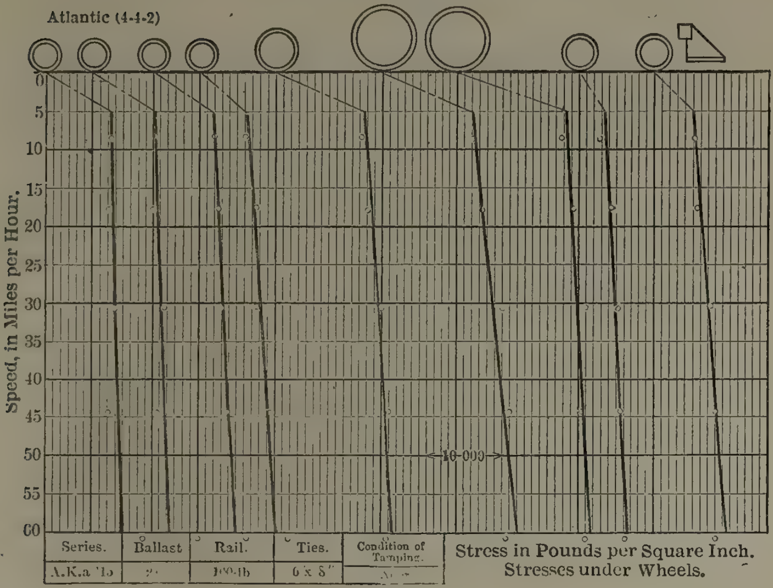


FIG. 86-a.

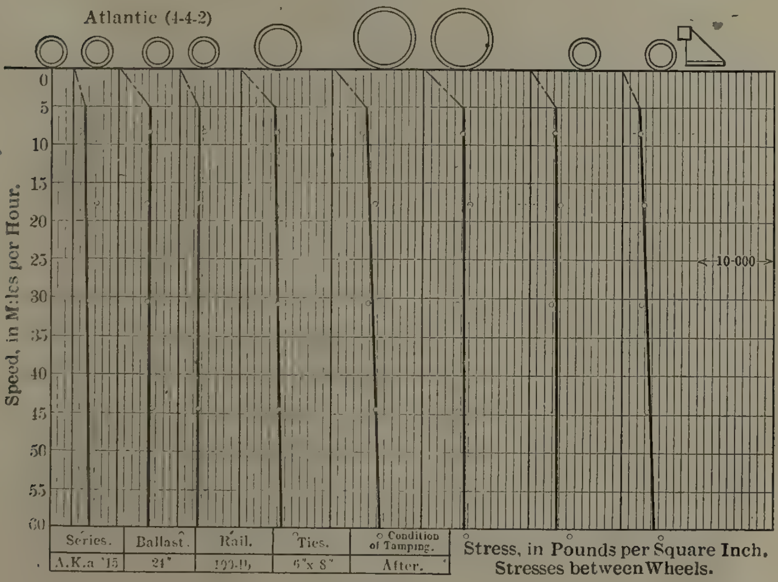
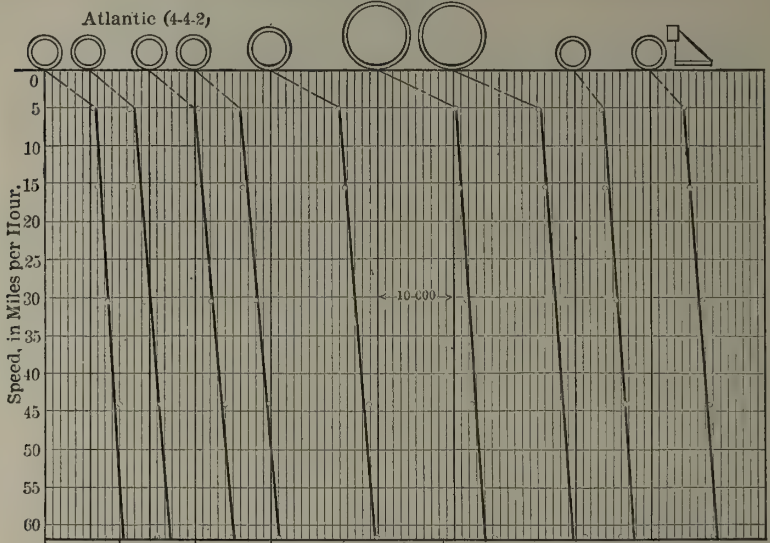


FIG. 86-b.

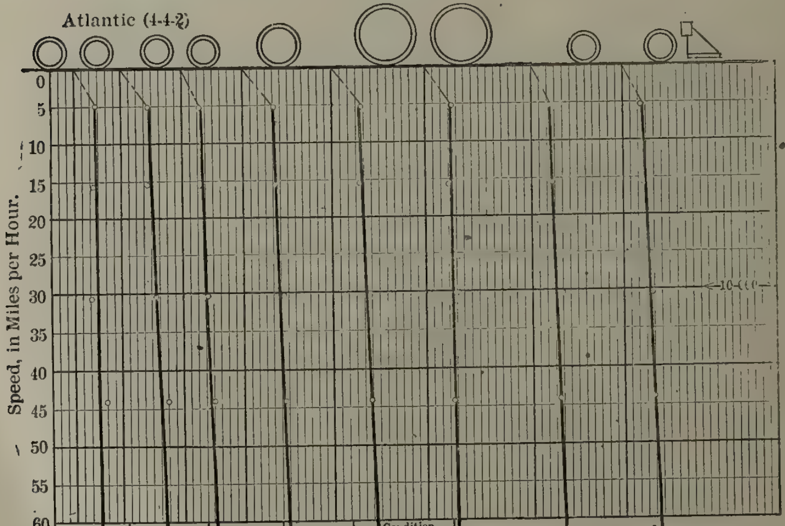
SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH ATLANTIC LOCOMOTIVE.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
A.B.a '15	12"	125-lb.	6"x 8"	After.

Stress, in Pounds per Square Inch.
Stresses under Wheels.

FIG. 87-a.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
A.B.a '15	12"	125-lb.	6"x 8"	After.

Stress, in Pounds per Square Inch.
Stresses between Wheels.

FIG. 87-b.

SPEED-STRESS DIAGRAMS.

MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH ATLANTIC LOCOMOTIVE.

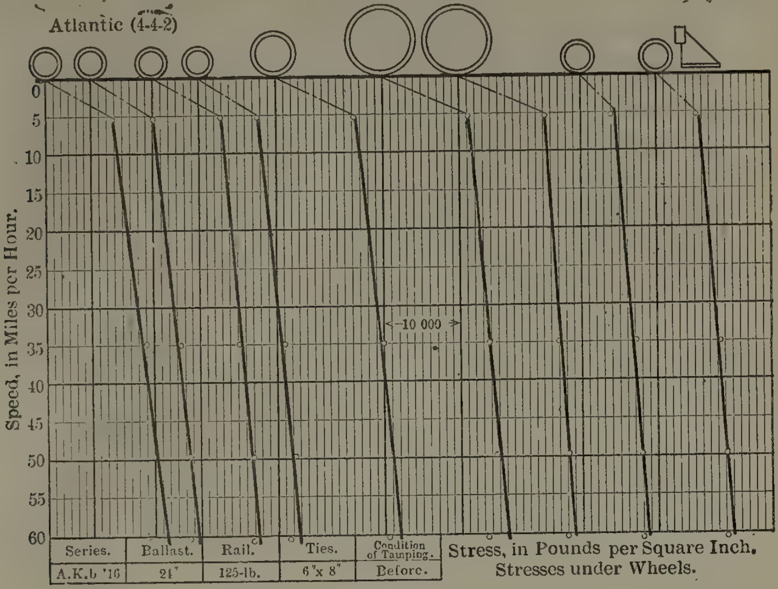


FIG. 88-a.

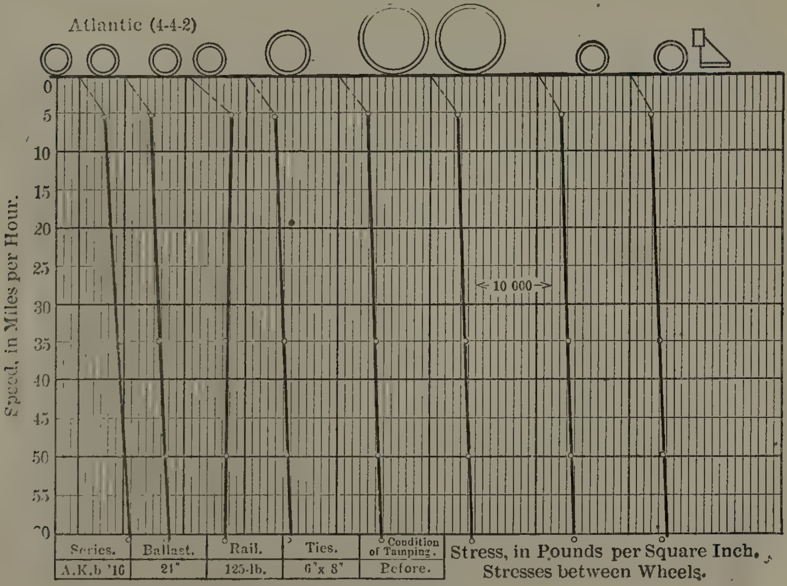
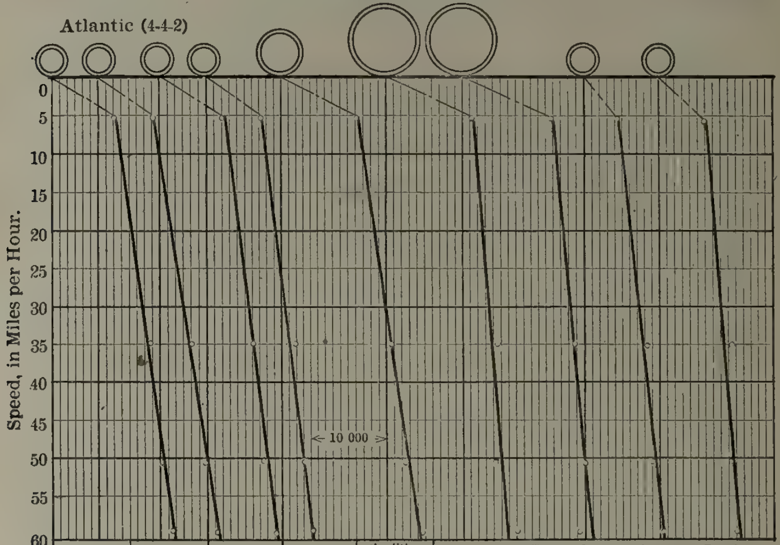


FIG. 88-b.

SPEED-STRESS DIAGRAMS.

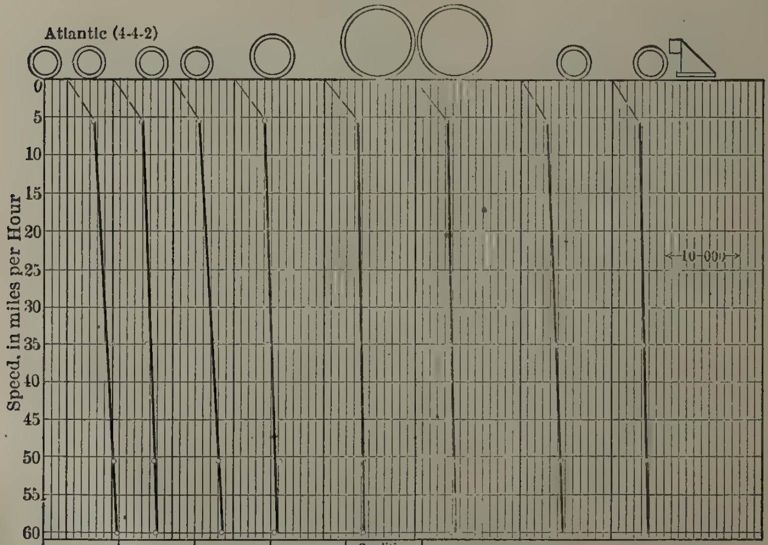
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH ATLANTIC LOCOMOTIVE.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
A.K.a '16	24"	125-lb.	6"x 8"	After.

Stress, in Pounds per Square Inch,
Stresses under Wheels.

FIG. 89-a.

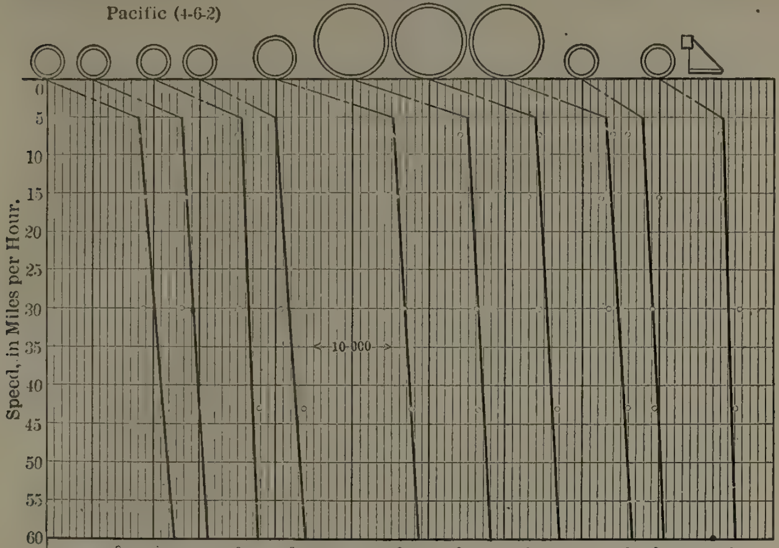


Series	Ballast	Rail	Ties	Condition of Tamping
A.K.a-'16	24"	125-lb.	6"x 8"	After

Stress, in Pounds per Square Inch.
Stresses between Wheels.

FIG. 89-b.

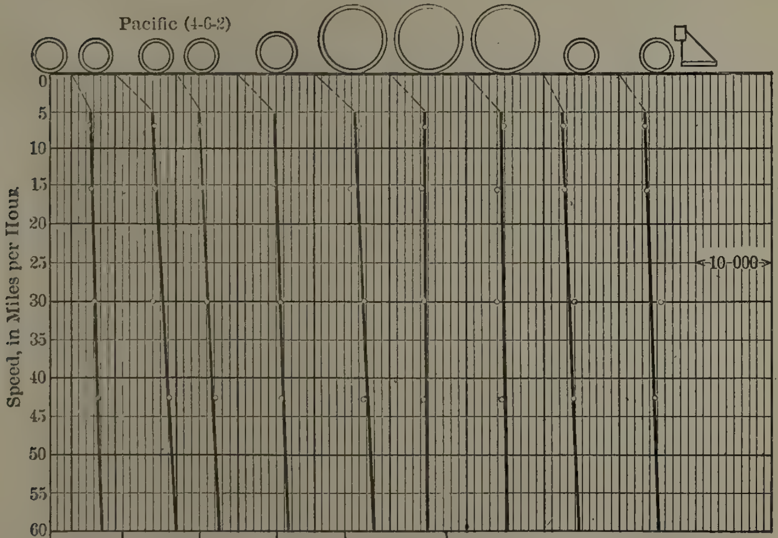
SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH PACIFIC LOCOMOTIVE.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
P.B.a '15	12"	85-lb.	6"x 8"	After.

Stress, in Pounds per Square Inch.
Stresses under Wheels.

FIG. 90-a.



Series.	Ballast.	Rail.	Ties.	Condition of Tamping.
P.B.a '15	13"	85-lb.	6"x 8"	After.

Stress, in Pounds per Square Inch.
Stresses between Wheels.

FIG. 90-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH PACIFIC LOCOMOTIVE.

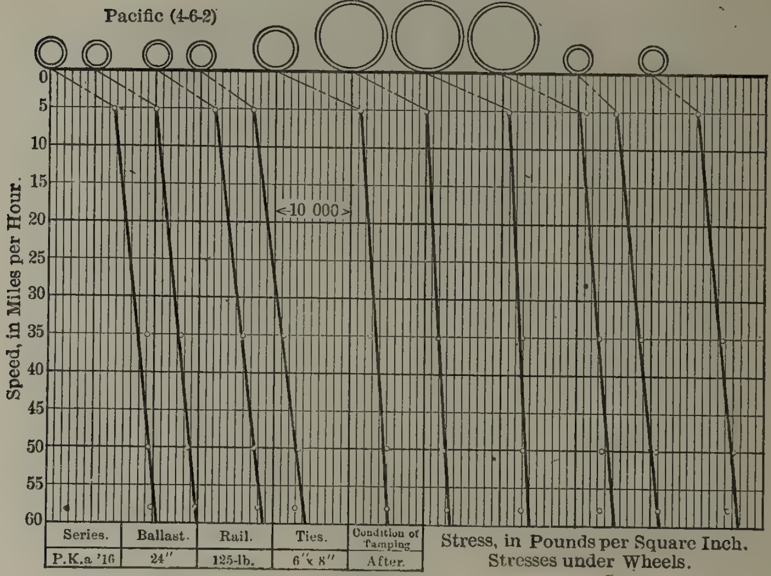


FIG. 91-a.

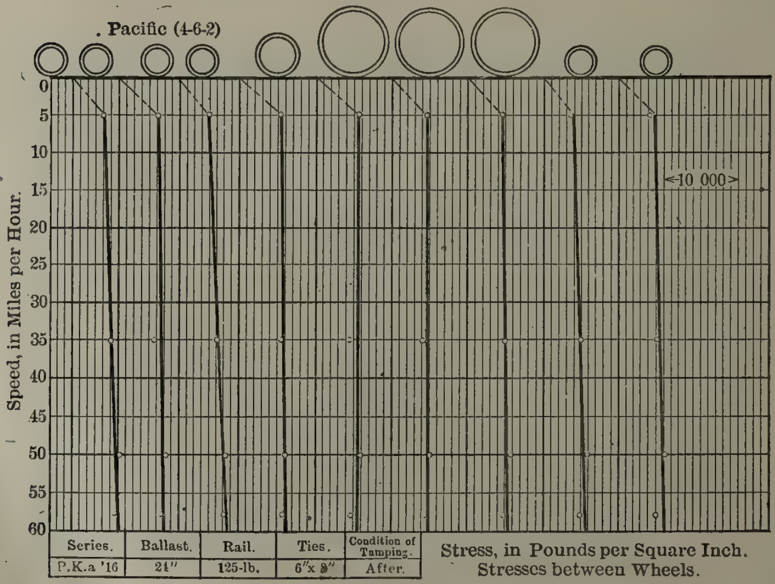


FIG. 91-b.

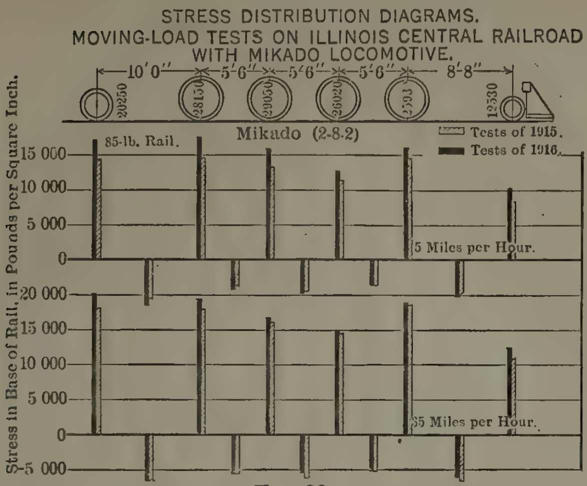

STRESS DISTRIBUTION DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

Fig. 92.

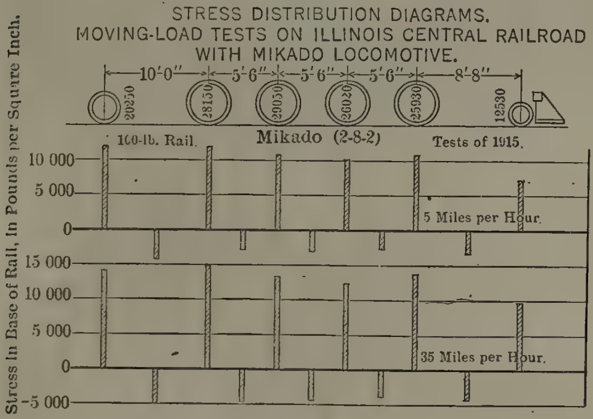

STRESS DISTRIBUTION DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

Fig. 93.

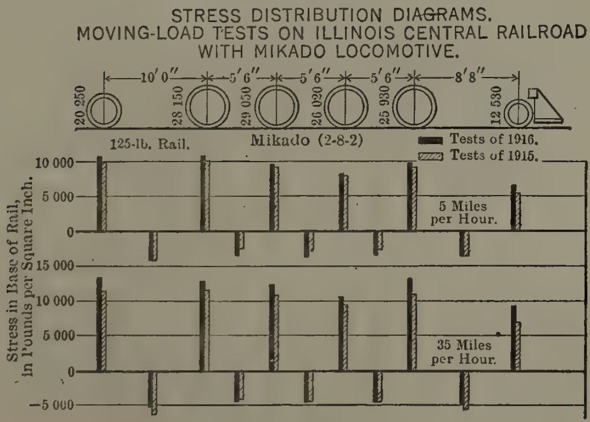

STRESS DISTRIBUTION DIAGRAMS.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.

Fig. 94.

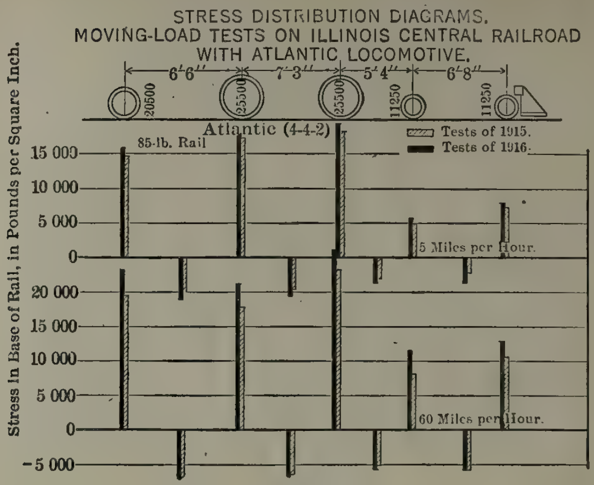


FIG. 95.

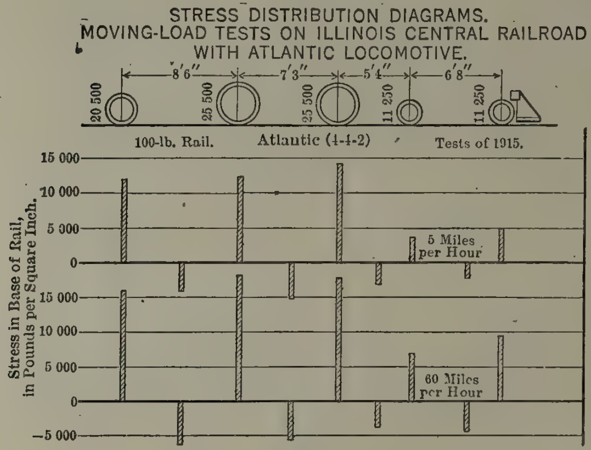


FIG. 96.

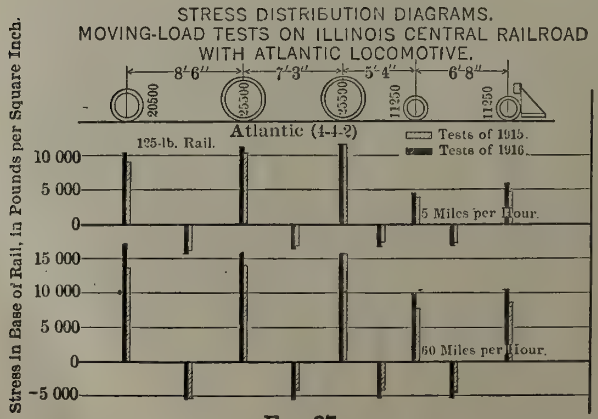


FIG. 97.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH MIKADO LOCOMOTIVE.

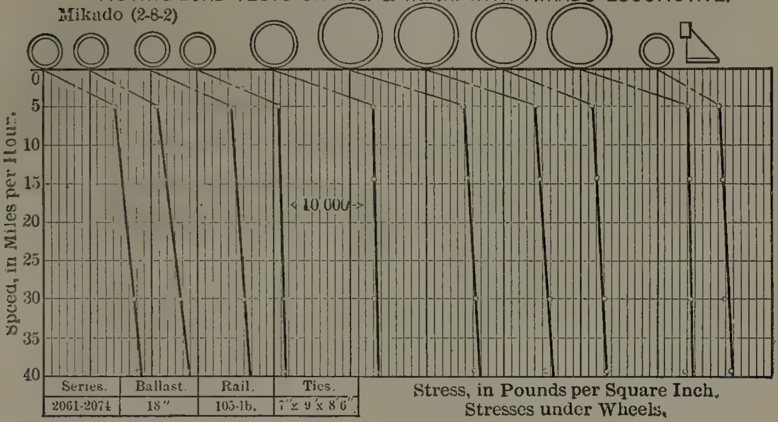


FIG. 98-a.

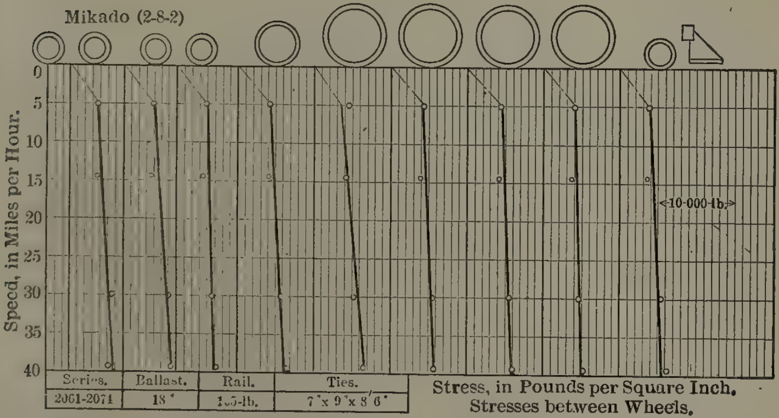


FIG. 98-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH PACIFIC FREIGHT LOCOMOTIVE.

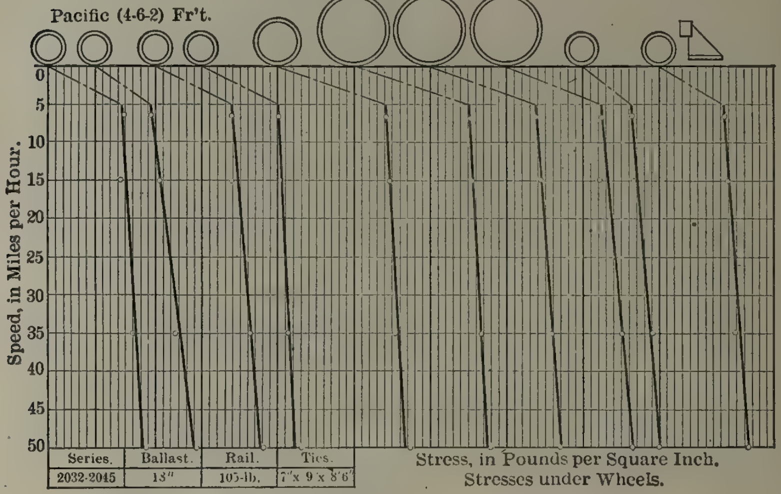


Fig. 99-a.

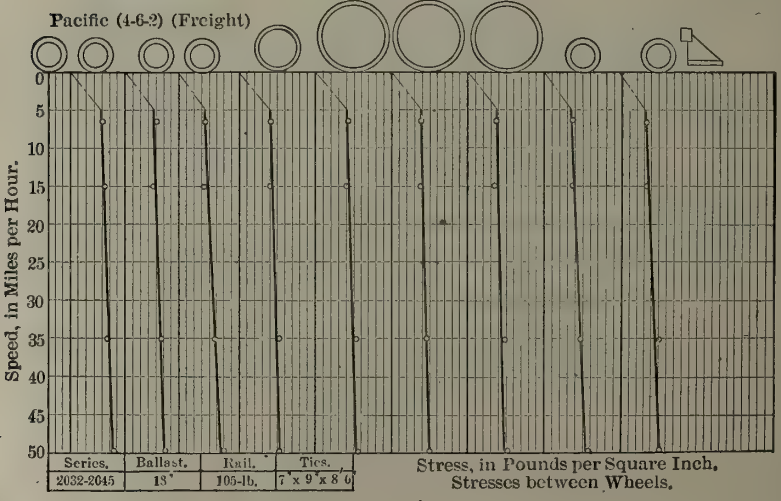


Fig. 99-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH PACIFIC PASSENGER LOCOMOTIVE.

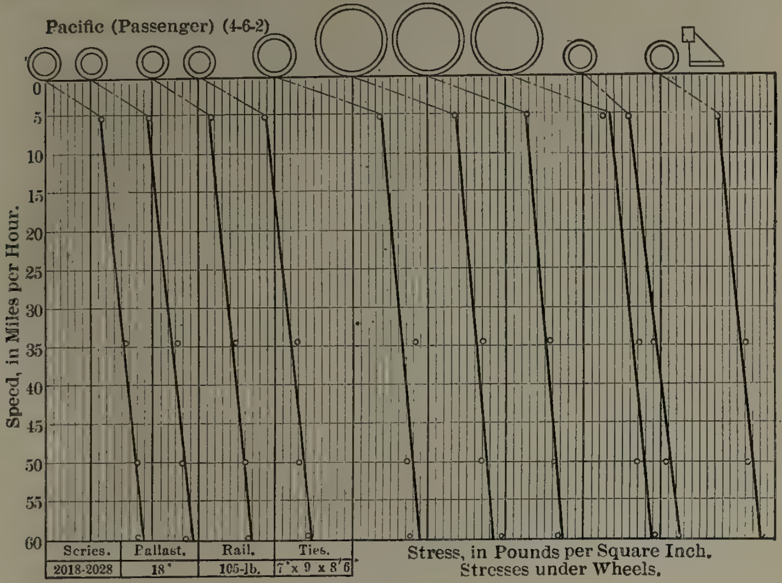


FIG. 100-a.

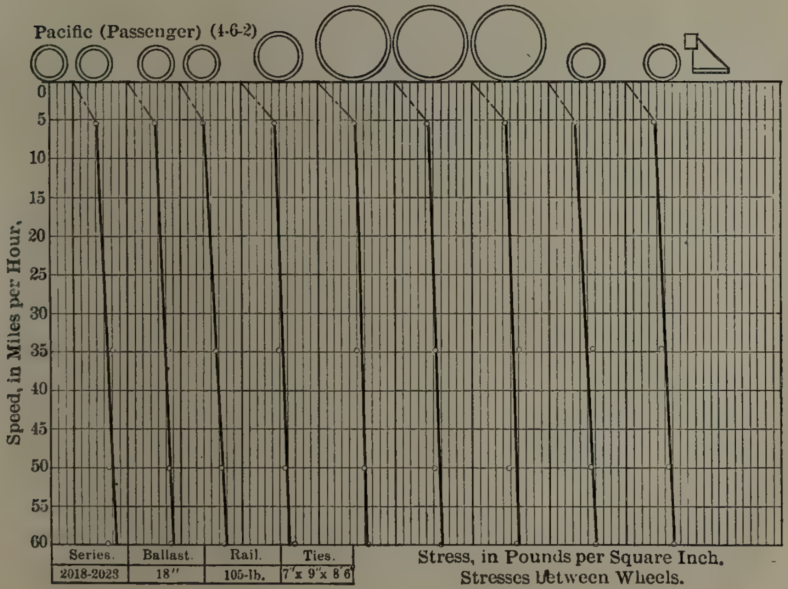


FIG. 100-b.

SPEED-STRESS DIAGRAMS.
MOVING-LOAD TESTS ON D.L. & W.R.R. WITH TEN-WHEEL LOCOMOTIVE.

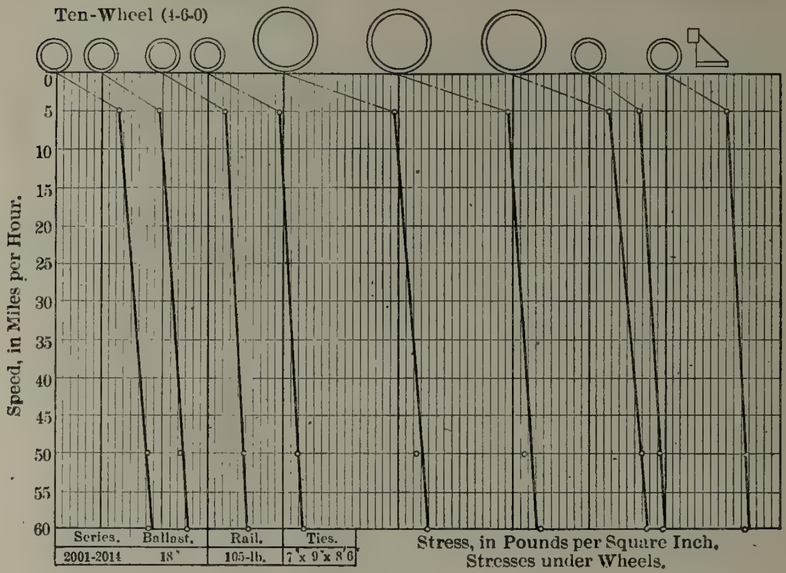


FIG. 101-a.

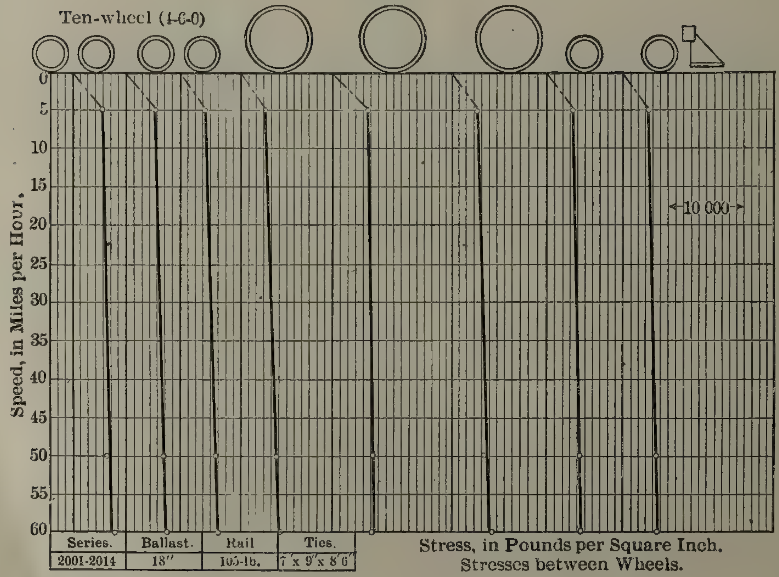


FIG. 101-b.

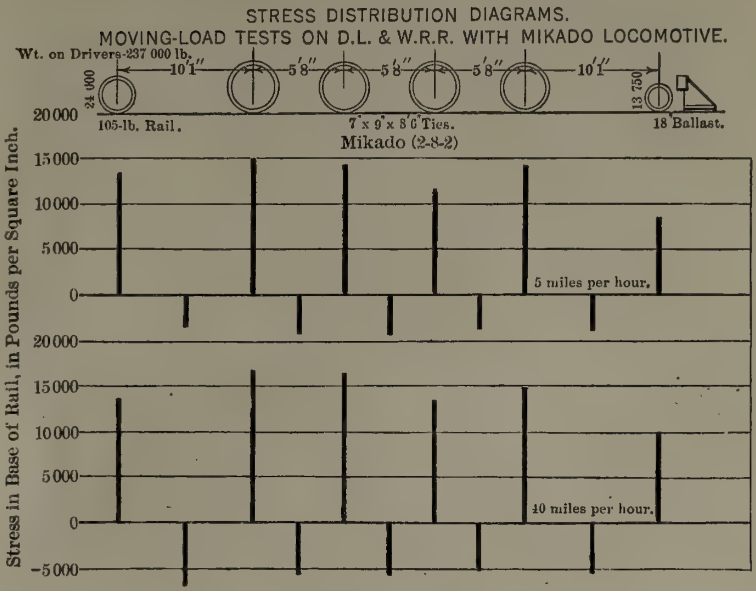


Fig. 102.

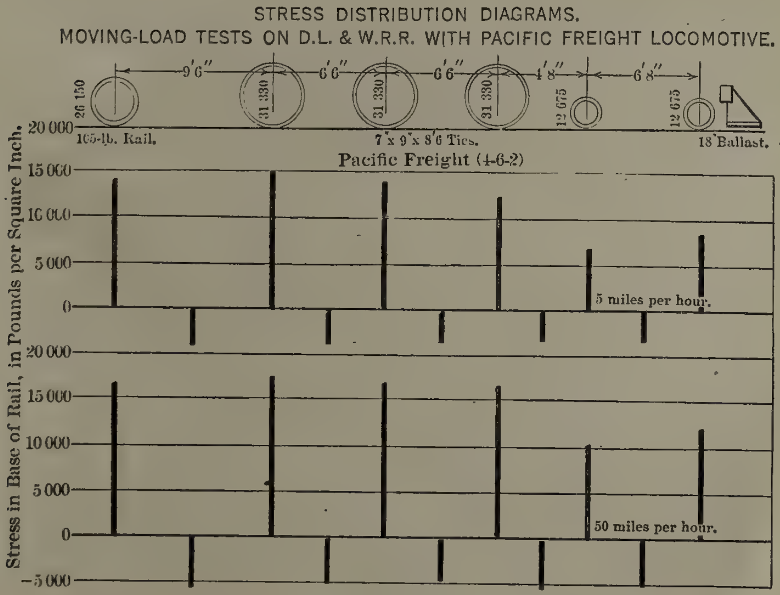


Fig. 103.

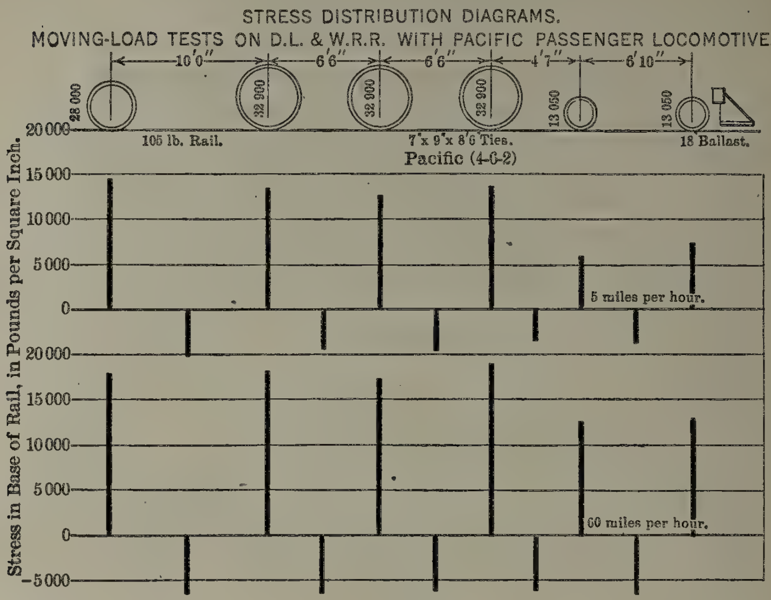


FIG. 104.

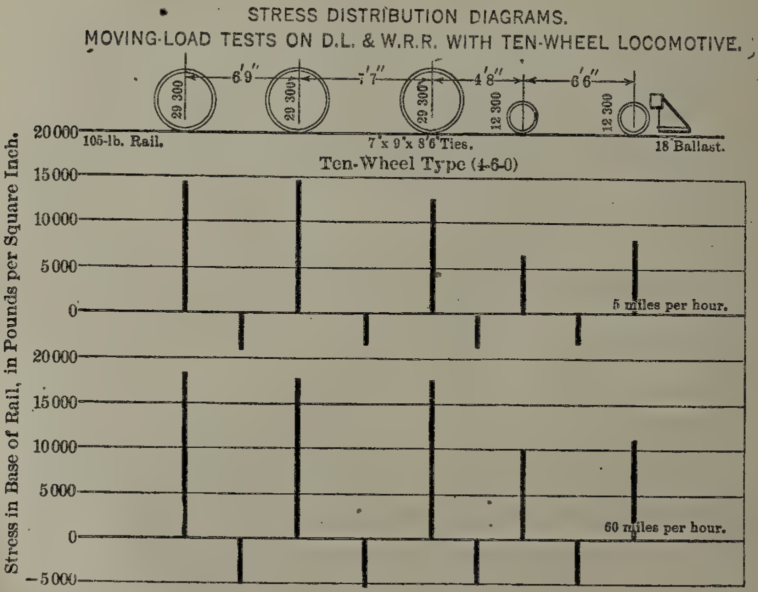


FIG. 105.

The definition of the term implies that the modulus of elasticity of rail-support is a constant for any given condition of track—that the track has the usual property of an elastic body. In the discussion of the data on track depression, it was shown that the depression of track may not be proportional to the load applied; under such conditions the modulus of elasticity of rail-support would not be a constant. The tests indicate conditions of track which may be classified in three groups. The plotted depressions may give a straight line passing through the origin as at a Fig. 106, denoting a constant modulus of elasticity—a condition which may be expected in well-tamped track and where the tie has a full bearing immediately below the rail and for some distance each way along its length, even when only a small load is applied. The plotted depression may form a straight line which passes to the right of the origin as at b, denoting that some condition exists such as the presence of some play between tie and ballast immediately below the rail necessitating the bending of the tie before a full and fair bearing is obtained along its length; in this case the depression may be found by the use of a constant modulus of elasticity of rail-support plus a constant. At c the condition is similar, except that the points do not give a straight line relation; in this case the relation of depression to load may be approximated by a constant modulus of elasticity of rail-support drawn to pass the points somewhat as shown in the figure. For track in poor condition, the relation of depression to load may be expected to vary from the straight-line relation even more than shown in the figure. As conditions of track vary greatly, the relation between track depression and load may be expected to cover a considerable range of values and conditions. It is evident that the constant modulus of elasticity of rail-support applies very well to the conditions of best track, and that for poor and indifferent track the actual relation between depression and load departs considerably from a straight-line relation.

Values of the modulus of elasticity of rail-support have been calculated from the data of the track depressions by adding the depressions at the several ties for the length of the depressed track or for the length for which the loads used are considered to affect the track depressions. The total load on the wheels within the length used was then divided by the number of ties in this length and by the tie spacing in inches. The values of the modulus of elasticity of rail-support are thus given in pounds per inch of length of rail per inch of depression. The symbol u is used to represent it. A continuous load of u pounds per inch of rail on each rail would depress the track one inch. For the locomotive loading, in computing the modulus of elasticity of rail-support the total track depression was used; the static tests with locomotive were all made on track in well-tamped condition. For the one-axle load and two-axle load tests the lines of the load-depression diagrams were studied and here some allowance was made for the play at light load for track conditions which gave indications of such play, net track depres-

TABLE 4—VALUES OF MODULUS OF ELASTICITY OF RAIL SUPPORT.

Depth of ballast, in inches.	Size of ties, in inches.	Condition of tamping.	85-LB. RAIL.			100-LB. RAIL.			125-LB. RAIL.	
			Locomotive.	One-Axle.	Two-Axle.	Locomotive.	One-Axle.	Two-Axle.	Locomotive.	One-Axle.
24	6 by 8	Before	....	1 170	1 180	....	....	1 090	....	1 640*
			....	1 190	....	....	1 080	1 100	....	1 820*
			....	1 640	....	....	1 030	....	....	1 600
			....	....	....	....	880	....	....	....
		Average......	....	1 330	1 180	....	1 000	1 090	....	1 690
24	6 by 8	After	1 650	....	....	1 510	1 710	....	1 540	1 920
			1 660	....	....	....	1 430	....	1 420	1 840
			1 570	....	....	....	....	....	1 800	1 560
			....	....	....	....	....	....	1 830	2 010
			....	....	....	....	....	....	1 880	....
		Average......	1 630	....	....	1 510	1 570	....	1 590	1 890

Depth of ballast, in inches.	Size of ties, in inches.	85-LB. RAIL.					
		BEFORE TAMPING.			AFTER TAMPING.		
		Locomotive.	One-Axle.	Two-Axle.	Locomotive.	One-Axle.	Two-Axle.
12	6 by 8	....	880*	910*	990	810	910
		....	910*	950*	1 040	1 000	870
		....	930*	....	1 000	940	....
		....	1 270*	....	....	....	....
		....	1 210*	....	....	....	....
	Average...........		1 030	930	1 010	920	890
12	7 by 9	....	1 300	800	1 230	....	880
		....	1 500	870	1 110	1 170	980
		....	1 060	950	1 150	....	....
		....	1 190	....	....	....	....
	Average...........		1 260	870	1 160	1 170	930
6	6 by 8	....	950	970	990	....	....
		....	810	880	1 100	....	....
		....	1 280	....	1 030	....	....
		....	1 030	....	1 180	....	....
		....	1 010	....	....	....	....
	Average..........		1 020	920	1 080	....	....

* This track, marked as "before tamping," seemed to be in as good condition as "after tamping."

sions being used for the calculations. In some cases a general compromise straight line was used. The values reported are given tentatively and may need empirical modifications later to fit into other experimental data.

In Table 4 are given the values of the modulus of elasticity of rail-support as calculated from the track depressions. The conditions of track are not very definitely stated, but even in track marked "before tamping" the track was in good surface and only in a few instances was the track in need of tamping. The values derived from the tests for the different methods of loading on the same track agree very well. There seems some tendency towards a higher value of the modulus in the track having the heaviest rail. It is apparent that the character and condition of the track greatly influences the magnitude of the modulus of elasticity of rail-support. The value of the modulus on the track of the Illinois Central Railroad with 24-in. ballast may be taken as about 1600 lbs. per inch per inch. This test stretch is on the northbound track. For the track on 6-in. and 12-in. ballast, the values are in the neighborhood of 1000, except for the track on 7x9-in. ties, where the values are higher, say about 1200. These last named stretches of test track are on the southbound track. Although the embankment for the two tracks was built at different times, it is not known that the two parts of the embankment have any special differences in condition. In all these test stretches, there is a tie spacing of 22 in. where the tests were made. For the track used for freight service, which was ballasted with 6 in. of cinders in not very compact condition, the value of the modulus of elasticity of rail-support

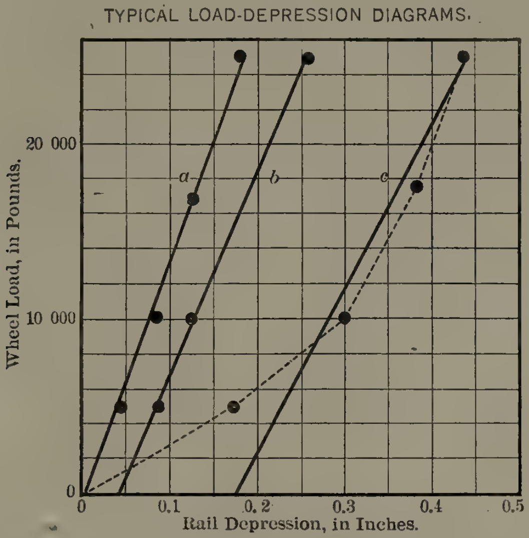


FIG. 106.

is about 750. For the track of the Champaign and Havana branch of the Illinois Central Railroad, with about 6 in. of fine cinder ballast above a light embankment of loam, tie spacing varying from 22 to 26 in. (56-lb. rail), the modulus of elasticity of rail-support found was about 530. At the time the track was not in good condition at the point where the test was made. Some of the ties were partially decayed.

For the track of the Delaware, Lackawanna & Western Railroad, information on the depression of track and the condition of the track is not complete and only an estimated value of the modulus of elasticity of rail-support can be given. This track was evidently stiffer than the track of the Illinois Central Railroad. The value, 2200 lbs. per inch per inch, is probably representative of this track. The track had 18 in. of trap-rock ballast below the tie and the material of the roadbed below was such that it was very solid. The spacing of the 7 x 9 in. x 8 ft. 6 in. ties averaged about 22 in.

48. *Bending Moment Coefficient and Stresses in Rail.*—It will be convenient in making calculations and comparisons to use the term bending moment coefficient as the coefficient by which the wheel load P may be multiplied to find the bending moment in the rail at a given point. Generally, the term will refer to the bending moment directly under a wheel load. In the case of a combination of wheels, the moment under a wheel will be expressed in terms of the wheel load at the given point. The bending moment coefficient will also be used in connection with the maximum negative bending moment. In this case the wheel load used in connection with the coefficient should be specified. The symbol K will represent the bending moment coefficient.

The sections of the rails used in the tests are shown in Fig. 107. The properties of the sections are given in Table 5.

In columns marked S in Table 6 are recorded fiber stresses in base of rail derived from the tests on the Illinois Central Railroad, the values being averages of those plotted in Figs. 69 to 91. The stresses are given in thousands of pounds per sq. in. Corresponding values of the bending moment coefficients are given in the columns to the right of the stresses (marked K). These were calculated from the stresses by the usual formula $M = KP = \frac{SI}{c}$. For the negative moments between drivers the average load on the adjacent drivers was used as P. For the negative moments between a driver and a truck or trailer, the load on the adjacent driver was used as P. It should be borne in mind that the tests were made on stretches of track having differing track conditions, and in making comparisons this should be taken into consideration.

Table 7 gives stresses and bending moment coefficients obtained in a similar manner from the tests on the track of the Delaware, Lackawanna & Western Railroad, near Dover, N. J.

The bending moment coefficients found in the tests with the several types of locomotive, given in the foregoing tables, are shown diagrammatically in Figs. 108 to 117.

In Fig. 118 the stresses in rail at speeds of 5 miles per hour and 35 or 60 miles per hour, taken from Table 6, are plotted for the three sections of rail.

Discussion of the results given in these tables and diagrams will be found in the following pages.

49. *Effect of Speed.*—The position of the plotted points in Figs. 69 to 91 indicates that a rectilinear relation between stress in rail and speed of locomotive fits the data more generally and more satisfactorily than any other form of relation. The variations of the plotted points from the straight lines of the diagrams are generally not greater than may be expected when variations in conditions of track and locomotive, errors of instruments and observations, and other accidental causes of variation are taken into account. Generally for any test the lines of a diagram are parallel or nearly so.

TABLE 5.—PROPERTIES OF SECTIONS OF RAILS USED IN TESTS.

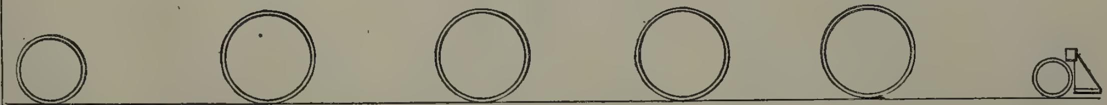
Rail section.	Area, in square inches.	MOMENT OF INERTIA.		SECTION MODULUS.		
				HORIZONTAL AXIS.		VERTICAL AXIS.
		For horizontal axis.	For vertical axis.	Base.	Head.	Base.
85-lb. Am. Soc. C. E. (worn)................	7.85	27.0-in.^{4}	7.3-in.^{4}	11.1-in.^{3}	10.1-in.^{3}	2.79-in.^{3}
100-lb. Am. Soc. C. E....	9.84	44.0 "	10.7 "	16.1 "	14.5 "	8.72 "
105-lb. D. L. & W........	10.23	47.6 "	10.0 "	17.2 "	14.7 "	3.72 "
125-lb. P. R. R...........	12.30	68.7 "	18.4 "	22.9 "	19.6 "	4.87 "

In Table 8 are given values of the increase in stress due to speed as obtained from the rectilinear relation of the diagrams. In the columns marked A the increase is expressed as pounds per sq. in. increase in stress for each mile per hour increase in speed above 5 miles per hour. In the column marked B the effect of speed is given in per cent. of the stress in the rail at 5 miles per hour for each mile per hour increase of speed above 5 miles per hour. It will be seen that the values for the increase for positive moment range from about 0.3 to 1.2 per cent. increase for each mile per hour increase in speed. Values higher than 0.9 per cent. are found in a number of cases. The increases found in the tests on the Delaware, Lackawanna & Western Railroad given in Table 9 are of the same character, but the values are somewhat smaller than those found in the tests on the Illinois Central Railroad.

It will be noted that the effect of speed for the several wheels and for the different rail sections given in the tables shows considerable variation. The cause of these variations is not known. It may lie partly in the locomotives, and partly in accidental conditions of the runs of the

TABLE 6.—STRESSES IN RAILS, S, AND BENDING MOMENT COEFFICIENTS, K, FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD.

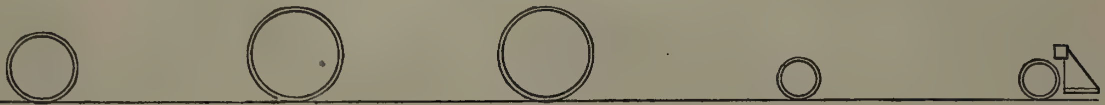
MIKADO (2–8–2)



Weight of rail, in pounds per yard.	Year.	Speed, in miles per hour.	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
85	1915	5	14.3	7.9	— 5.6	— 2.3	14.7	5.8	— 3.5	— 1.4	13.3	5.0	— 4.4	— 1.8	11.4	4.9	— 3.5	— 1.5	14.7	6.4	— 4.7	— 2.0	8.4	7.7
		35	18.1	9.9	— 7.4	— 2.8	17.9	7.1	— 5.5	— 2.1	16.1	6.1	— 6.1	— 2.3	14.7	6.4	— 5.1	— 2.1	18.6	7.8	— 6.6	— 2.6	10.9	9.7
85	1916	5	17.1	9.4	— 6.6	— 2.6	17.7	7.0	— 4.0	— 1.6	16.0	6.1	— 4.7	— 1.9	12.9	5.5	— 3.5	— 1.5	16.1	6.9	— 5.1	— 2.2	10.3	9.1
		35	20.1	11.0	— 7.0	— 2.7	19.4	7.6	— 5.3	— 2.1	16.8	6.4	— 5.3	— 2.1	15.0	6.4	— 5.0	— 2.1	18.9	8.1	— 6.1	— 2.6	12.4	11.0
100	1915	5	12.0	9.6	— 4.2	— 2.5	12.0	6.9	— 2.8	— 1.7	10.8	5.9	— 3.0	— 1.9	10.1	6.2	— 2.6	— 1.7	10.8	6.7	— 3.3	— 2.2	7.2	9.2
		35	14.2	11.3	— 4.8	— 2.7	14.8	8.5	— 4.6	— 2.6	13.4	7.4	— 4.4	— 2.6	12.4	7.7	— 3.7	— 2.3	13.9	8.6	— 4.4	— 2.7	9.7	12.5
125	1915	5	9.8	11.0	— 4.2	— 3.5	10.1	8.1	— 2.3	— 2.0	9.4	7.3	— 2.7	— 2.4	8.0	7.0	— 2.5	— 2.3	9.4	8.4	— 3.5	— 3.3	5.5	10.0
		35	11.5	13.0	— 6.1	— 5.0	11.6	9.4	— 4.3	— 3.4	11.0	8.7	— 4.4	— 3.6	9.8	8.6	— 4.4	— 3.9	11.1	9.8	— 5.3	— 4.7	7.0	12.8
125	1916	5	10.9	12.3	— 4.2	— 3.4	10.8	8.8	— 3.4	— 2.7	9.7	7.6	— 3.6	— 3.0	8.3	7.3	— 3.2	— 2.8	10.1	8.9	— 3.5	— 3.1	6.6	12.0
		35	13.4	15.1	— 5.1	— 4.1	12.9	10.5	— 4.3	— 3.4	12.4	9.8	— 4.5	— 3.7	10.7	9.4	— 4.5	— 4.0	13.5	11.9	— 4.5	— 4.0	9.5	17.4

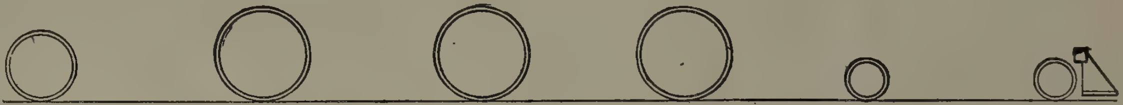
TABLE 6.—Continued.

ATLANTIC (4–4–2)



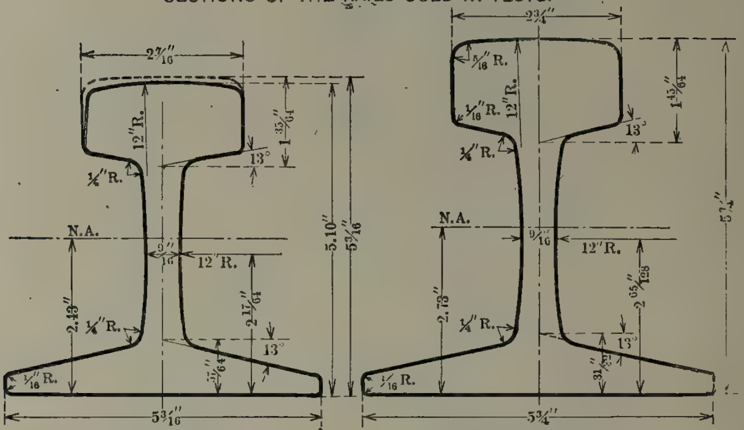
Weight of rail, in pounds per yard.	Year.	Speed, in miles per hour.	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
85	1915	5	14.6	7.9	— 5.0	— 2.2	17.4	7.5	— 4.7	— 2.1	18.4	7.9	— 3.0	— 1.3	4.8	4.7	— 2.4	— 2.4	7.1	7.0
		60	19.4	10.6	— 7.4	— 3.2	17.7	7.7	— 6.5	— 2.8	23.2	10.1	— 5.2	— 2.3	8.0	7.9	— 5.8	— 5.7	10.4	10.3
85	1916	5	15.9	8.6	— 6.1	— 2.7	17.9	7.8	— 5.5	— 2.4	19.6	8.5	— 3.8	— 1.7	5.7	5.6	— 3.6	— 3.6	7.9	7.8
		60	23.8	12.6	— 7.4	— 3.3	21.2	9.3	— 7.0	— 3.2	26.1	11.4	— 5.7	— 2.5	11.5	11.2	— 5.8	— 5.8	12.8	12.9
100	1915	5	11.8	9.3	— 4.3	— 2.8	12.4	7.8	— 5.2	— 3.4	14.4	9.2	— 3.2	— 2.1	3.6	5.1	— 2.2	— 3.3	5.0	7.2
		60	15.7	12.3	— 6.5	— 4.1	18.2	11.5	— 5.5	— 3.5	17.7	11.2	— 3.7	— 2.3	6.6	9.5	— 4.4	— 6.3	9.5	13.7
125	1915	5	9.1	10.1	— 3.7	— 3.4	10.4	9.4	— 3.3	— 3.2	11.6	10.4	— 2.5	— 2.3	4.0	8.0	— 2.5	— 5.3	4.7	9.5
		60	13.6	14.7	— 5.4	— 4.8	13.9	12.5	— 4.0	— 3.6	15.6	14.0	— 4.2	— 3.8	7.6	15.5	— 4.6	— 9.4	8.5	17.3
125	1916	5	10.3	11.5	— 4.1	— 3.7	11.3	10.1	— 3.9	— 3.5	11.8	10.6	— 3.2	— 3.0	4.5	9.2	— 3.4	— 7.0	6.0	12.2
		60	17.2	19.2	— 5.6	— 5.1	15.8	14.2	— 5.4	— 4.9	15.9	14.2	— 5.2	— 4.7	9.8	19.7	— 5.0	—10.3	10.4	21.2

PACIFIC (4–6–2)



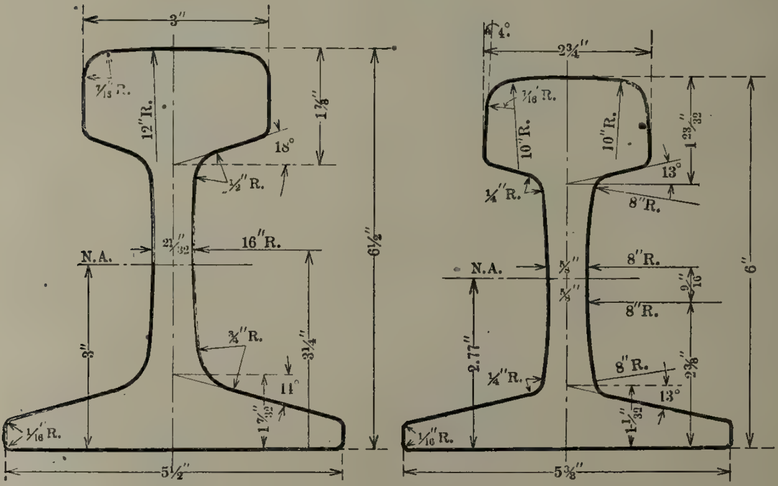
Weight of rail, in pounds per yard.	Year.	Speed, in miles per hour.	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*	*S*	*K*
85	1915	5	15.3	7.7	— 5.3	— 2.4	15.0	6.7	— 4.5	— 1.9	13.8	5.7	— 4.5	— 1.9	13.1	5.8	— 2.5	— 1.1	7.8	7.0	— 3.5	— 8.1	8.5	7.7
		60	18.9	9.5	— 7.9	— 3.5	18.2	8.1	— 4.8	— 2.1	17.2	7.1	— 5.2	— 2.2	16.7	7.4	— 4.5	— 2.0	10.7	9.7	— 5.0	— 4.5	10.1	9.1
125	1916	5	11.3	11.7	— 5.6	— 5.1	10.1	9.3	— 4.7	— 4.1	10.9	9.2	— 4.7	— 4.1	10.2	9.3	— 3.8	— 3.5	5.2	9.6	— 5.0	— 9.3	6.1	11.3
		60	15.3	15.9	— 5.5	— 5.0	13.5	12.3	— 5.0	— 4.4	14.0	11.8	— 5.3	— 4.7	14.9	13.6	— 5.7	— 5.2	11.7	21.6	— 6.3	—11.7	11.6	21.5

SECTIONS OF THE RAILS USED IN TESTS.



85-lb. Am. Soc. C.E.
(Worn)

100-lb. Am. Soc. C.E.



125-lb. Penn. R.R.

105-lb. D.L. & W. R. R.

FIG. 107.

tests. Although the runs were all made with the counterweight in its lowest position as it passed the middle instrument, part of the tests were made with the three instruments on the rail at the right side of the locomotive and part with the three instruments at the left side, and hence in one case the counterweights on the other side of the locomotive opposite the three instruments were ahead, and in the other case behind, the position of the middle instrument. A study of the tests shows no variations traceable to these differences of conditions.

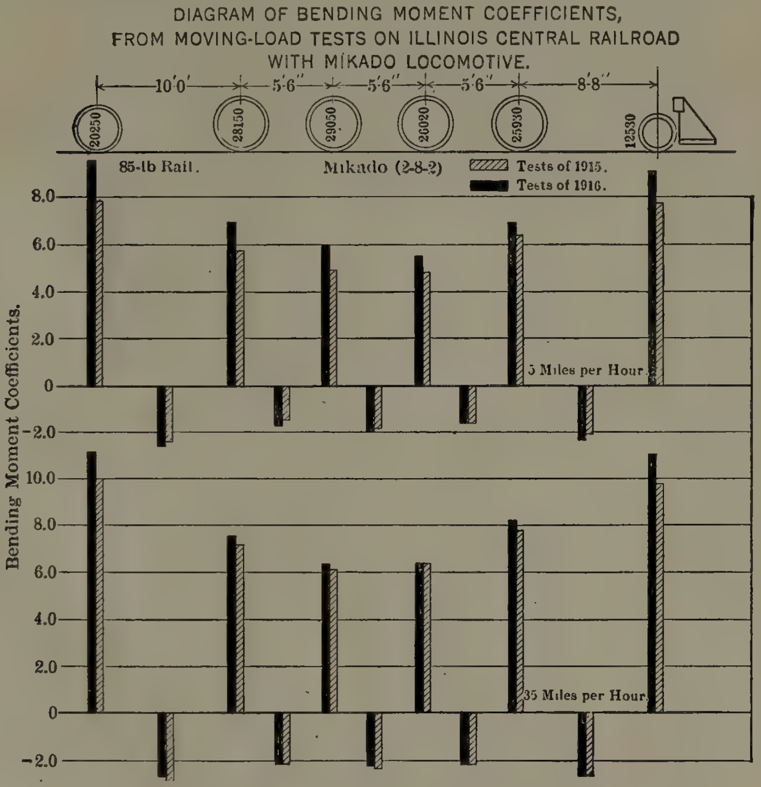


DIAGRAM OF BENDING MOMENT COEFFICIENTS, FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

FIG. 108.

The heavier rail section appears to give a somewhat higher proportional increase of stress with increase of speed than the lighter. The indications in the tests on track of the Illinois Central Railroad are that the Mikado locomotive gives a rate of increase somewhat greater than the Atlantic and the Pacific. The tender trucks give a still higher rate of increase, though, of course, the amount of the stress is less than that under the drivers.

The porportional increase in the stress for negative moment is large and rather irregular, as would be expected from the smaller value of this stress and the greater variations of conditions to which it is subjected. The sum of the stresses for positive moment and negative moment shows greater uniformity in the tests than does either set of stresses.

Exceptions from uniformity of action are found in the tests. In Fig. 82, the stresses under the rear driver are less at high speeds than at low speeds, and the data at the several speeds are consistent. In other instances one driver or one truck wheel shows a much higher increase with speed than do the other wheels.

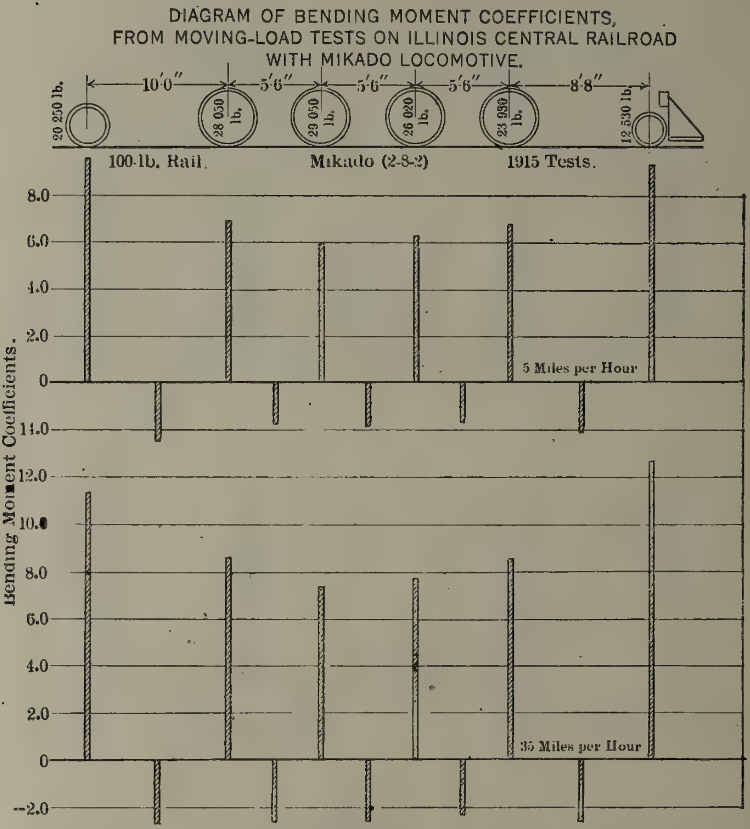


Fig. 109.

It should be remembered that the diagrams and tests give the average of a large number of runs, and, of course, the increases found for individual runs are considerably greater than the average values.

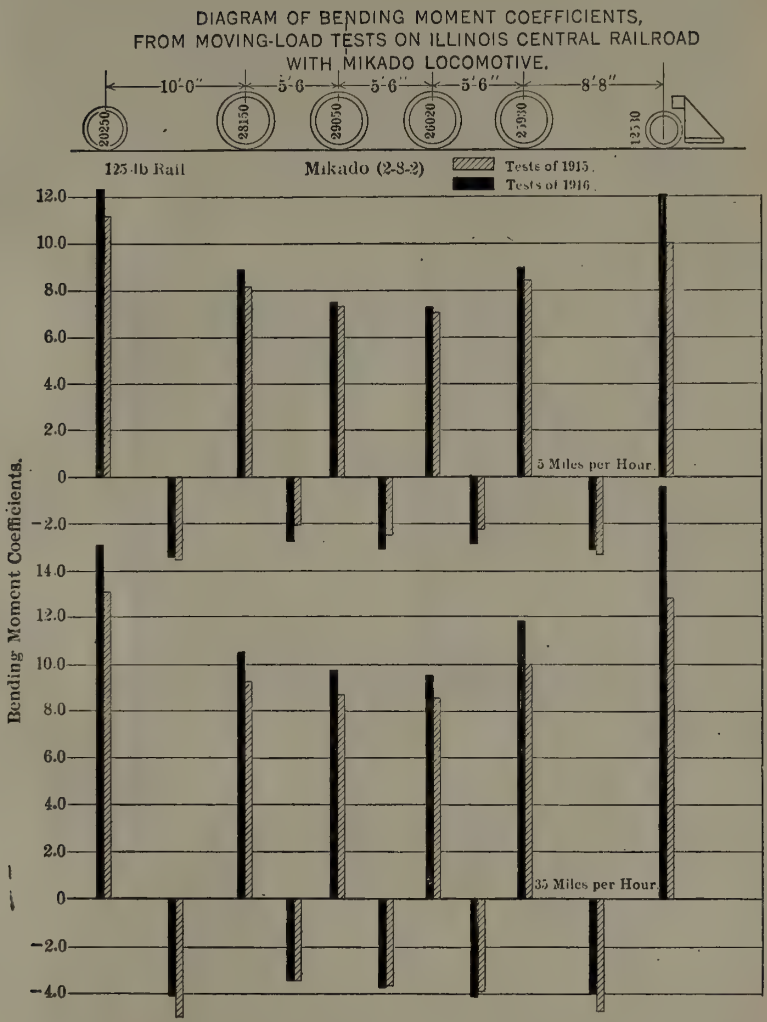


DIAGRAM OF BENDING MOMENT COEFFICIENTS,
FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH MIKADO LOCOMOTIVE.
10'-0"
5'-6
5'-6"
5'-6"
8'-8"
20250
28150
29050
26020
25930
12530
125-lb Rail
Mikado (2-8-2)
▨ Tests of 1915.
■ Tests of 1916.
Bending Moment Coefficients.
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
5 Miles per Hour.
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
35 Miles per Hour.

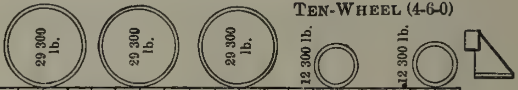
Fig. 110.

No discussion of the cause of the increased stress at the higher speeds will be made at the present time.

50. *Influence of Rail Section.*—In structural members the bending moment for a given load is usually independent of the section of a beam or girder which carries load, and the fiber stress in the beam is inversely proportional to the section modulus, $\frac{I}{c}$. For the track structure it has been shown by analysis that for a one-axle load the bending moment developed varies with the rail section, becoming larger as the moment of inertia of the section is increased; and, therefore, in calculating the fiber stress produced by a given load in a given rail section the value of the bending moment developed with the use of that rail section must be known. For a two-axle load or a three-axle load or for a combination of driver loads and truck wheel loads the magnitude of the bending moment will still be dependent upon the rail section, but not to the same extent as with a single load; and the influence of the rail section upon the bending moment developed will also depend upon the wheel

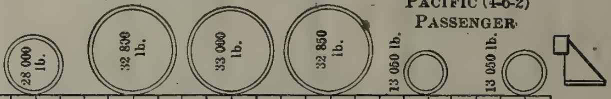
TABLE 7.—STRESSES IN RAIL, *S*, AND BENDING MOMENT COEFFICIENTS, *K*, FROM MOVING-LOAD TESTS ON DELAWARE, LACKAWANNA & WESTERN RAILROAD.

TEN-WHEEL (4-6-0)



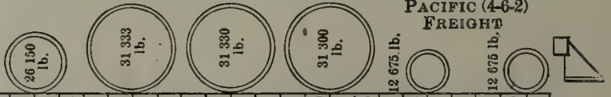
Weight of Rail, in Pounds per Yard.	Speed, in miles per hour.	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K
105	5	14.3	8.4	-4.0	-2.4	14.4	8.5	-3.4	-2.0	12.7	7.5	-3.5	-2.1	6.5	9.1	-3.3	-4.6	8.2	11.5
	60	18.3	10.8	-5.0	-2.9	17.7	10.4	-5.2	-3.0	17.7	10.4	-4.8	-2.9	9.8	13.7	-4.9	-6.9	11.0	15.4

PACIFIC (4-6-2) PASSENGER



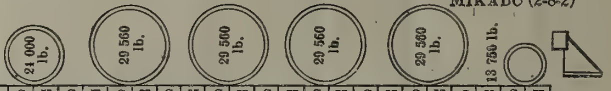
Weight of Rail, in Pounds per Yard.	Speed, in miles per hour.	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K
105	5	14.6	9.0	-5.1	-2.7	13.5	7.1	-4.4	-2.3	12.7	6.6	-4.5	-2.4	13.5	7.1	-3.4	-1.8	5.9	7.8	-3.7	-4.9	7.5	9.9
	60	17.6	10.8	-6.5	-3.4	19.2	9.5	-6.3	-3.3	17.3	9.1	-6.2	-3.2	19.0	10.0	-6.0	-3.1	12.6	16.6	-5.4	-8.5	13.0	17.2

PACIFIC (4-6-2) FREIGHT



Weight of Rail, in Pounds per Yard.	Speed, in miles per hour.	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K
105	5	14.2	9.4	-4.0	-2.2	15.1	8.3	-3.7	-2.0	14.0	7.7	-3.5	-1.9	12.4	6.8	-3.4	-1.9	6.6	9.0	-3.4	-4.6	8.5	11.6
	50	16.8	11.1	-5.4	-3.0	17.4	9.6	-5.0	-2.8	17.2	9.5	-4.7	-2.6	16.6	9.1	-5.5	-3.0	10.1	13.7	-5.2	-7.0	11.8	16.0

MIKADO (2-8-2)



Weight of Rail, in Pounds per Yard.	Speed, in miles per hour.	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K
105	5	13.2	9.5	-3.5	-2.0	14.9	8.7	4.2	-2.4	14.1	8.2	-4.5	-2.6	11.6	6.7	-3.8	-2.2	14.1	8.2	-3.7	-2.2	8.4	10.5
	40	13.5	9.7	-6.6	-3.8	16.7	9.7	-5.6	-3.8	16.5	9.6	-5.7	-3.3	13.6	7.9	-5.0	-2.9	14.7	8.5	-5.5	-3.2	9.9	12.4

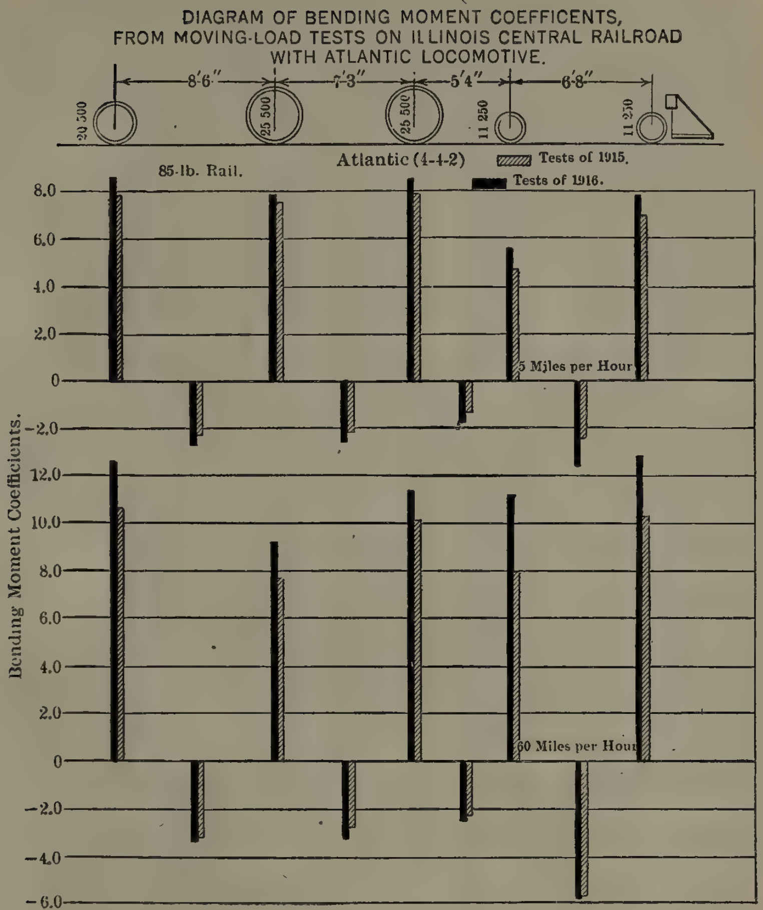


DIAGRAM OF BENDING MOMENT COEFFICENTS,
FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.
8′6″
7′3″
5′4″
6′8″
20 500
25 500
25 500
11 250
11 250
Atlantic (4-4-2)
85-lb. Rail.
▨ Tests of 1915.
■ Tests of 1916.
5 Miles per Hour
60 Miles per Hour
Bending Moment Coefficients.
8.0
6.0
4.0
2.0
0
−2.0
12.0
10.0
8.0
6.0
4.0
2.0
0
−2.0
−4.0
−6.0

FIG. 111.

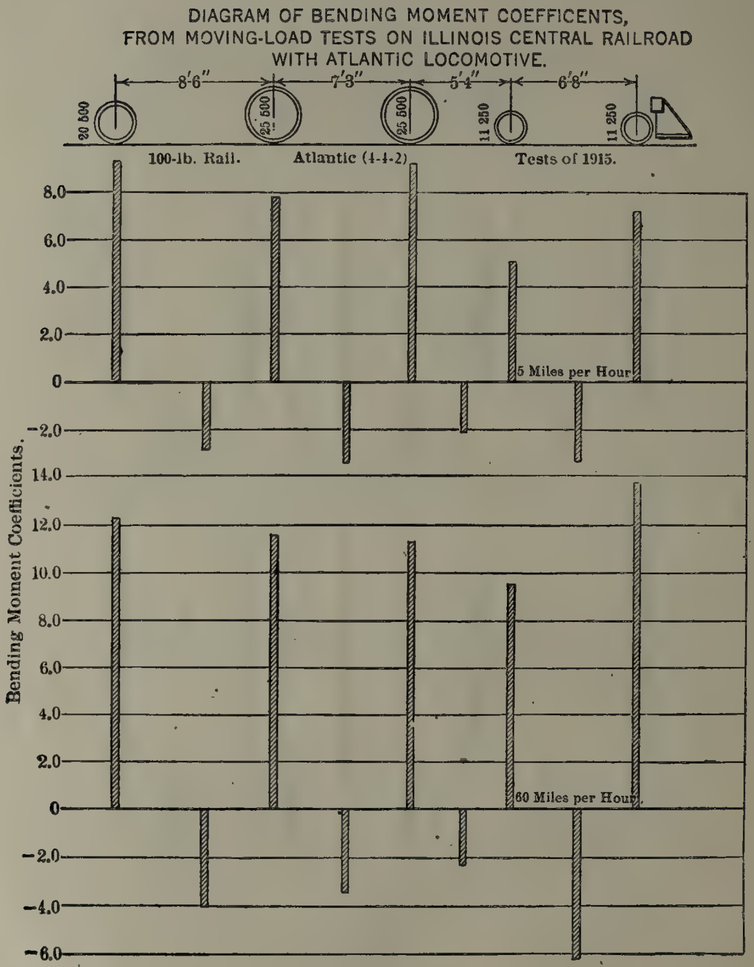


DIAGRAM OF BENDING MOMENT COEFFICENTS,
FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.
8′6″
7′3″
5′4″
6′8″
20 500
25 500
25 500
11 250
11 250
100-lb. Rail.
Atlantic (4-4-2)
Tests of 1915.
Bending Moment Coefficients.
8.0
6.0
4.0
2.0
0
-2.0
5 Miles per Hour
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
-4.0
-6.0
60 Miles per Hour.

Fig. 112.

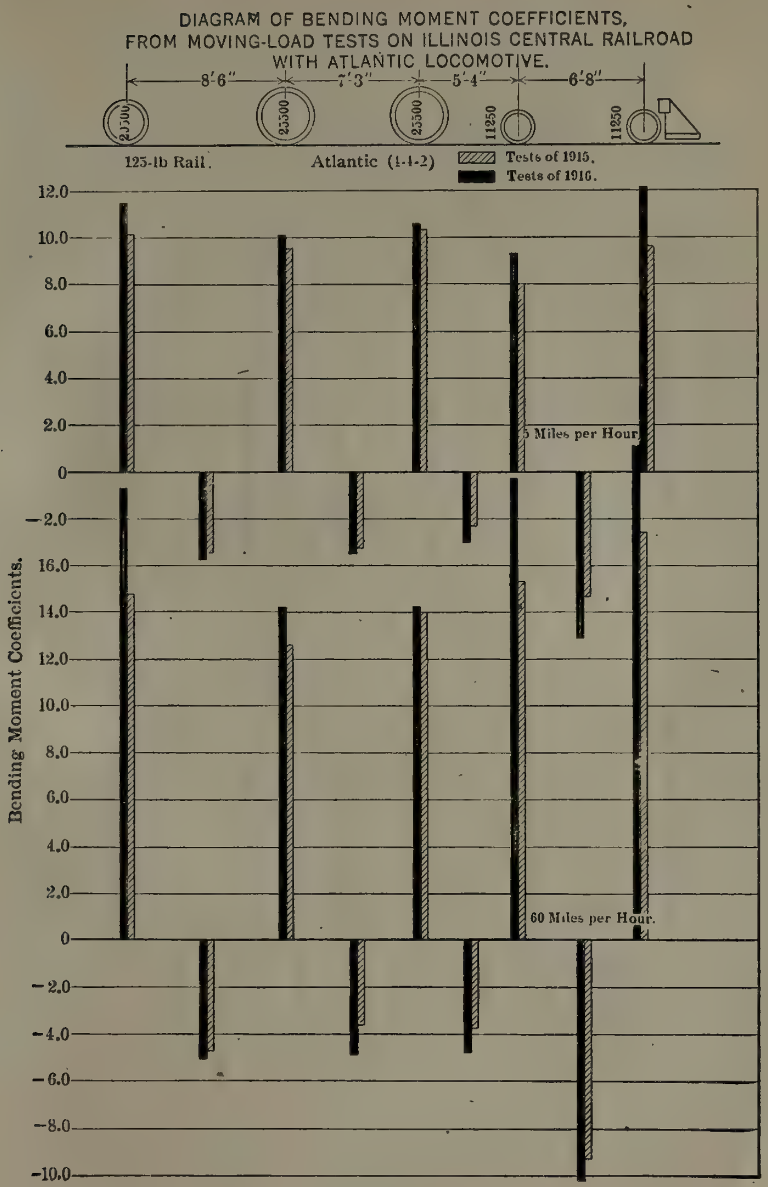


DIAGRAM OF BENDING MOMENT COEFFICIENTS,
FROM MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD
WITH ATLANTIC LOCOMOTIVE.
8′6″
7′3″
5′4″
6′8″
25500
25500
25500
11250
11250
125-lb Rail.
Atlantic (4-4-2)
Tests of 1915.
Tests of 1916.
5 Miles per Hour.
60 Miles per Hour.
Bending Moment Coefficients.
12.0
10.0
8.0
6.0
4.0
2.0
0
−2.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
−2.0
−4.0
−6.0
−8.0
−10.0

Fig. 113.

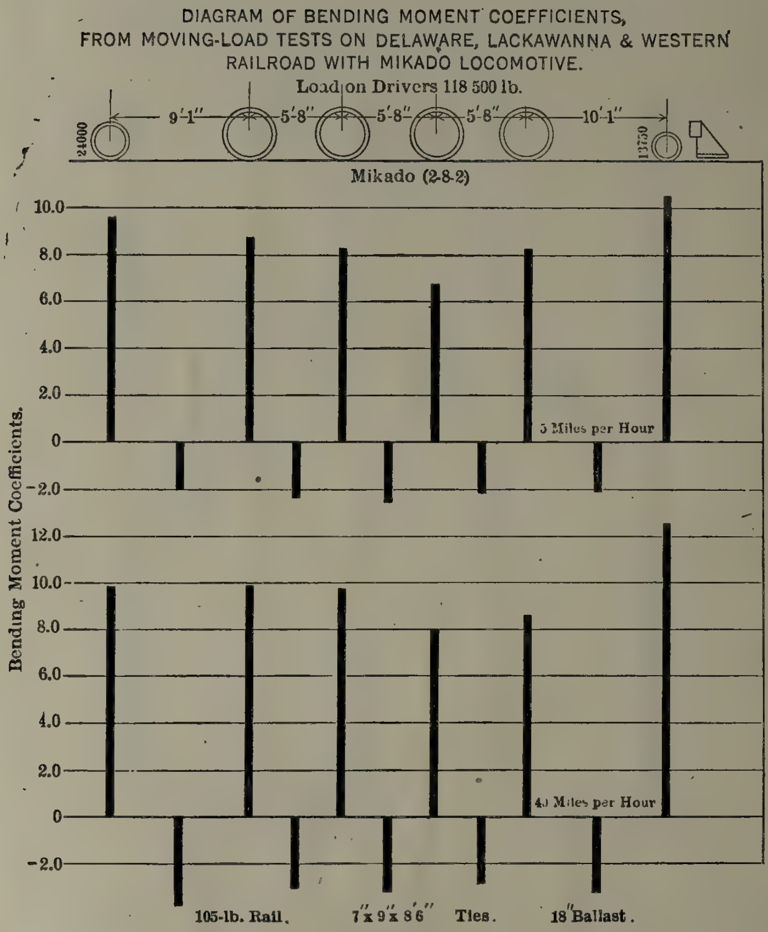


DIAGRAM OF BENDING MOMENT COEFFICIENTS,
FROM MOVING-LOAD TESTS ON DELAWARE, LACKAWANNA & WESTERN
RAILROAD WITH MIKADO LOCOMOTIVE.
Load on Drivers 118 500 lb.
9'-1"
5'-8"
5'-8"
5'-8"
10'-1"
24000
13750
Mikado (2-8-2)
Bending Moment Coefficients.
10.0
8.0
6.0
4.0
2.0
0
-2.0
5 Miles per Hour
12.0
10.0
8.0
6.0
4.0
2.0
0
-2.0
40 Miles per Hour
105-lb. Rail.
7"x 9"x 8' 6" Ties.
18" Ballast.

FIG. 114.

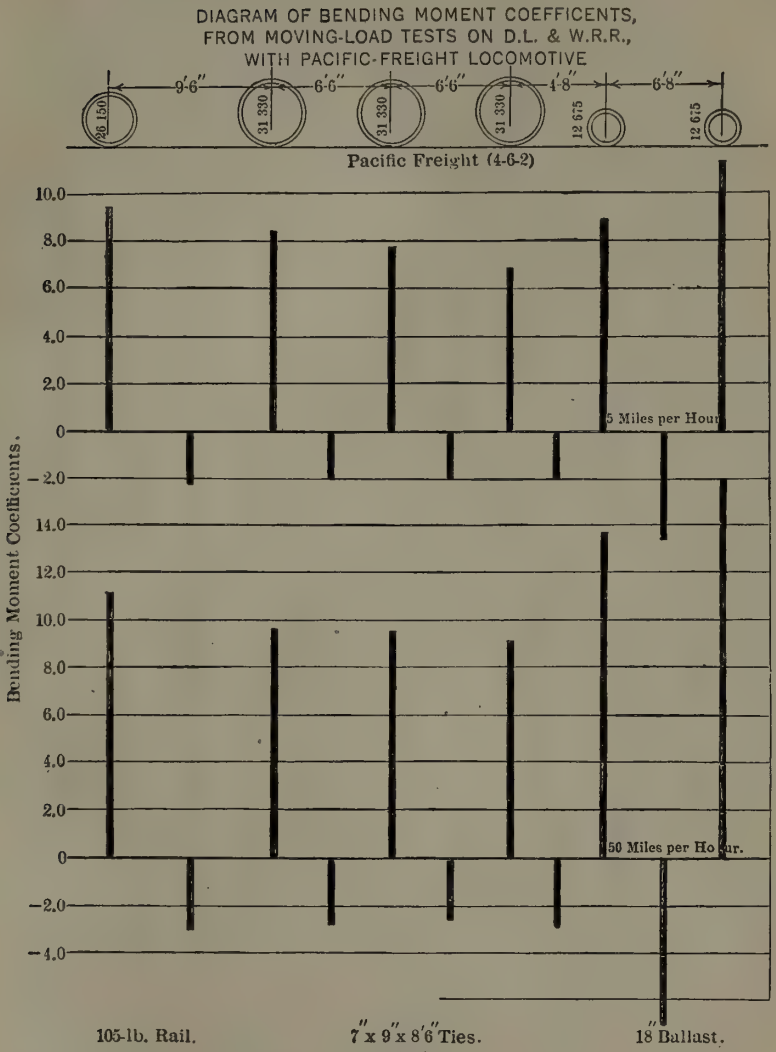
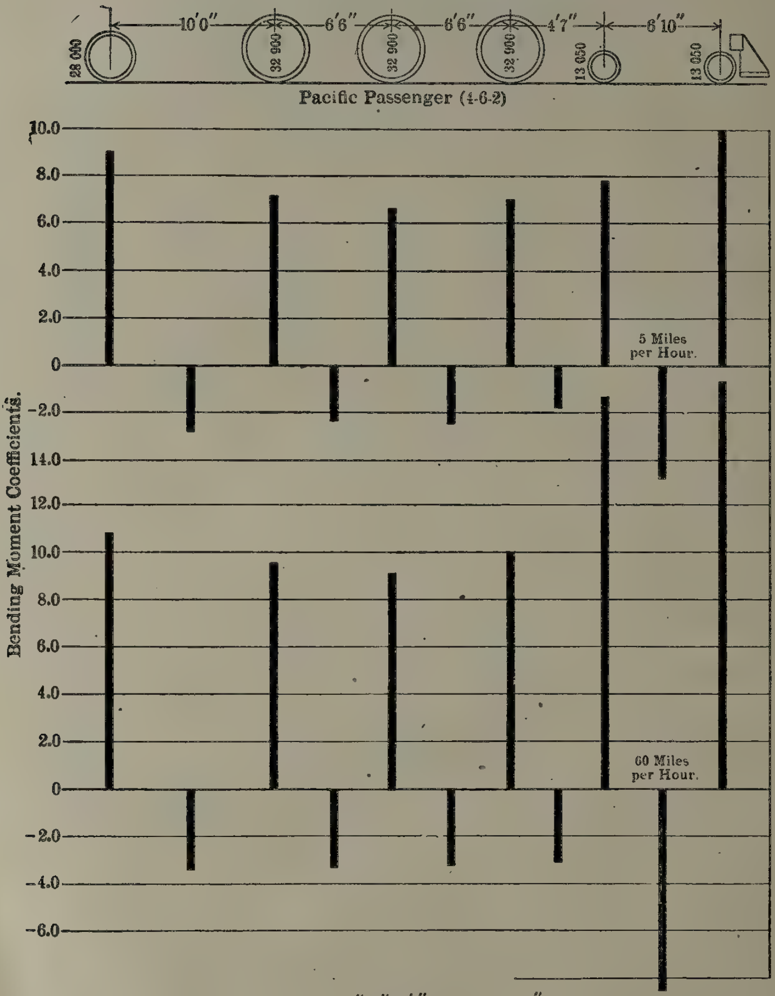


DIAGRAM OF BENDING MOMENT COEFFICENTS,
FROM MOVING-LOAD TESTS ON D.L. & W.R.R.,
WITH PACIFIC-FREIGHT LOCOMOTIVE
9′6″
6′6″
6′6″
4′8″
6′8″
26 150
31 330
31 330
31 330
12 675
12 675
Pacific Freight (4-6-2)
Bending Moment Coefficients.
10.0
8.0
6.0
4.0
2.0
0
−2.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
−2.0
−4.0
5 Miles per Hour
50 Miles per Hour.
105-lb. Rail.
7″ x 9″ x 8′6″ Ties.
18″ Ballast.

Fig. 115.

DIAGRAM OF BENDING MOMENT COEFFICIENTS,
FROM MOVING-LOAD TESTS ON D. L. & W. R.R.,
WITH PACIFIC PASSENGER LOCOMOTIVE.



105-lb. Rail. 7" x 9" x 8'6" Ties. 18" Ballast.

FIG. 116.

DIAGRAMS OF BENDING MOMENT COEFFICIENTS.
FROM MOVING-LOAD TESTS ON D.,L. & W.R.R., WITH TEN-WHEEL LOCOMOTIVE.

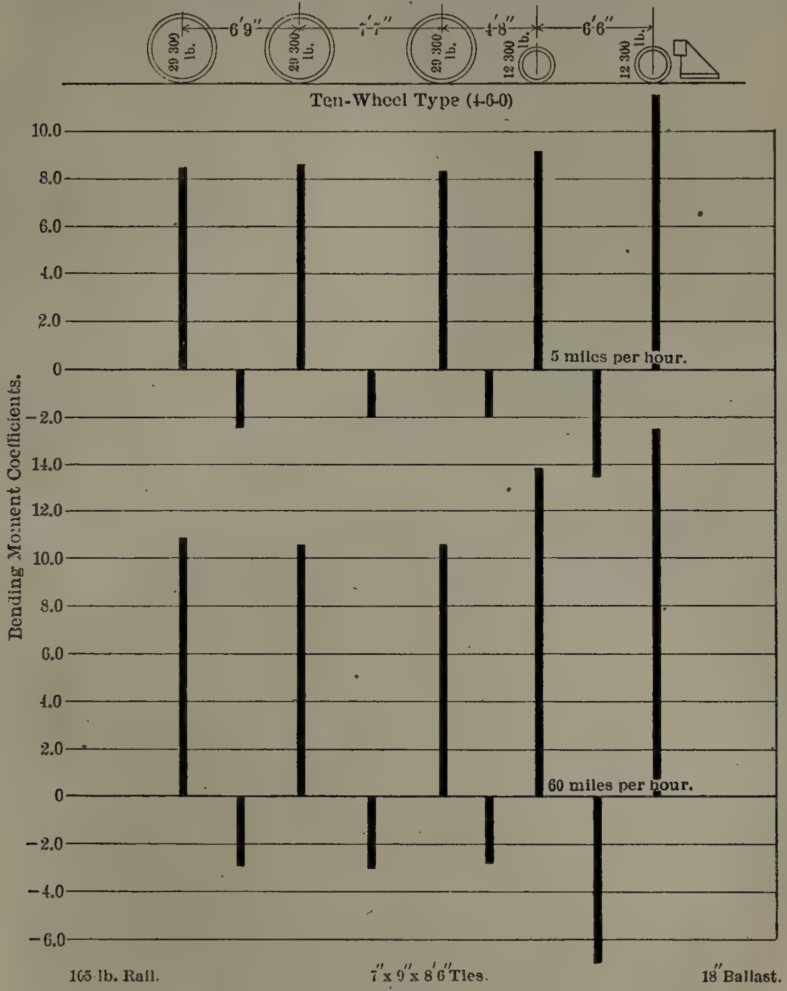


Fig. 117.

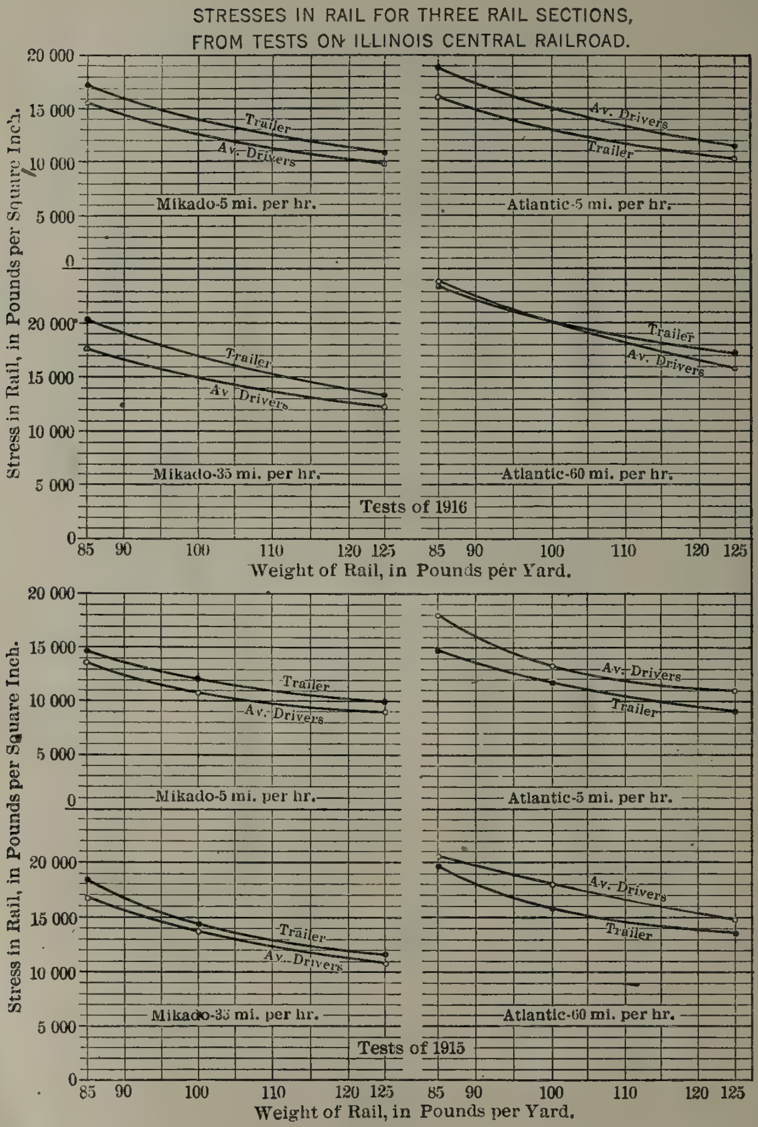
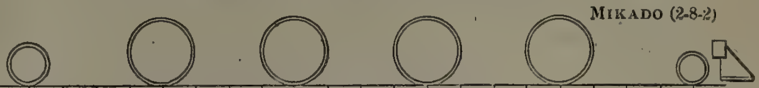
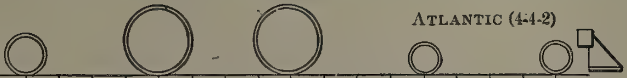
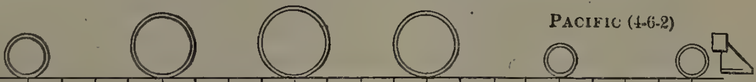

STRESSES IN RAIL FOR THREE RAIL SECTIONS, FROM TESTS ON ILLINOIS CENTRAL RAILROAD.

FIG. 118.

spacing. The general analytical relations involving the effect of the rail section upon the bending moment have already been derived. Values found from the tests will now be presented. It will be most convenient to use in the discussion the bending moment coefficient *K* by which the wheel load *P* may be multiplied to get the bending moment at the load or at a point between loads.

TABLE 8.—Increase in Stress in Rail Due to Speed.

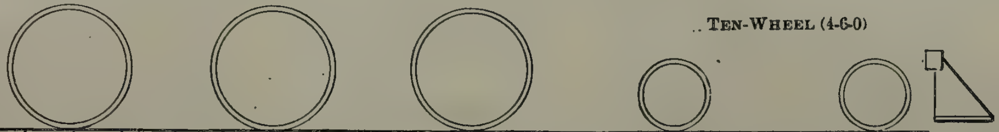
Tests on Illinois Central Railroad.

Weight of Rail, in Pounds per Yard.	Year.	 MIKADO (2-8-2)																					
		A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
85	1915	132	0.93	53	0.98	120	0.82	56	1.73	96	0.77	53	1.30	120	1.10	53	1.60	107	0.74	60	1.28	81	0.95
85	1916	108	0.64	24	0.45	78	0.44	3.9	0.95	29	0.18	21	0.42	81	0.59	41	1.30	72	0.44	39	0.77	80	0.73
100	1915	75	0.63	21	0.51	93	0.78	48	1.90	91	0.88	45	1.50	77	0.77	38	1.50	102	0.95	38	1.20	85	1.20
125	1915	57	0.51	[illegible]	1.50	50	0.49	67	2.90	55	0.58	57	2.10	62	0.77	62	2.40	55	0.58	59	1.70	54	0.98
125	1916	85	0.78	32	0.87	70	0.65	28	0.83	90	0.92	30	1.00	78	0.94	43	1.40	115	1.20	35	1.20	95	1.50
				 ATLANTIC (4-4-2)																			
				A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*		
85	1915			96	0.65	30	0.59	53	0.29	32	0.76	53	0.30	40	1.40	94	2.10	63	1.30	93	1.30		
85	1916			133	0.84	25	0.45	59	0.33	32	0.65	119	0.61	34	0.91	104	2	41	1.20	95	1.20		
100	1915			71	0.60	40	0.93	116	0.86	5	0.11	58	0.40	9	0.32	55	1.50	40	1.80	82	1.60		
125	1915			82	0.90	31	0.84	[illegible]	0.59	13	0.42	73	0.63	31	1.20	66	1.70	38	1.50	69	1.50		
125	1916			124	1.20	28	0.71	82	0.72	27	0.71	75	0.63	35	1.10	95	2.10	29	0.88	80	1.30		
		 PACIFIC (4-6-2)																					
		A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
85	1915	66	0.43	47	0.89	58	0.40	6	0.12	60	0.43	13	0.30	66	0.50	36	1.10	53	0.68	27	0.75	28	0.35
125	1916	73	0.65	-2	0.04	62	0.61	5.5	0.12	57	0.52	11	0.23	86	0.84	35	0.91	118	2.30	24	0.17	100	1.60

The results are presented graphically, the values of the bending moment coefficients obtained at the drivers and other loads being plotted against the moment of inertia of the rail section. Fig. 119 gives the values from the tests on the Illinois Central Railroad for one-axle load and two-axle load applied statically and for three types of locomotive at two speeds. The values at the left side of each diagram, plotted for a moment of inertia of 27, are results obtained with the worn 85-lb. rail (see Table 5 for properties of the rail sections). The values on the right side of each diagram, plotted for a mement of inertia of 68.7, are results obtained with the 125-lb. rail. In the case of the one-axle and two-axle loads results are also given for the 100-lb. rail, the moment of inertia

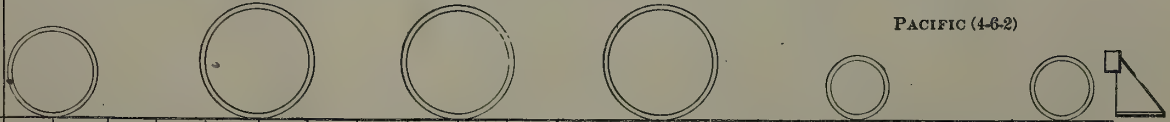
TABLE 9.—Increase in Stress in Rail Due to Speed.
Tests on Delaware, Lackawanna and Western Railroad.

Ten-Wheel (4-6-0)



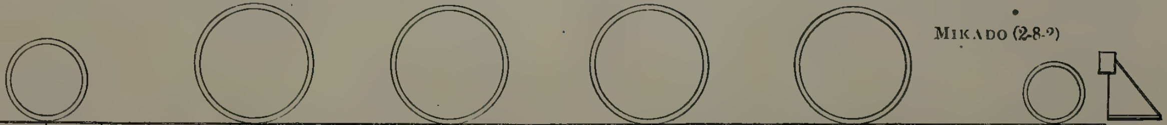
Weight of Rail, in Pounds per Yard.	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
105	73	0.51	18	0.45	60	0.42	33	0.97	91	0.72	24	0.67	60	0.92	29	0.88	51	0.62

Pacific (4-6-2)



Weight of Rail, in Pounds per Yard.	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	
105	55	0.37	25	0.50	86	0.63	35	0.79	84	0.66	31	0.69	98	0.72	47	1.39	122	2.06	49	1.33	100	1.33	Pass.
105	58	0.41	31	0.78	51	0.34	29	0.78	71	0.51	27	0.76	93	0.75	47	1.37	78	1.18	40	1.18	73	0.86	Frt.

Mikado (2-8-2)



Weight of Rail, in Pounds per Yard.	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
105	9	0.06	89	2.53	52	0.35	40	0.95	69	0.49	31	0.76	57	0.49	34	0.90	17	1.21	52	1.39	43	0.51

of the section being 44. The moving load tests with the Mikado and Atlantic locomotives on the 100-lb. rail were made in 1915 and, therefore, with the old form of stremmatograph, while the tests with the 85-lb. and 125-lb. rails, whose results are plotted in Fig. 119, were made in 1916 with the new form of stremmatograph. For this reason the tests with the Mikado and Atlantic locomotives on the 100-lb. rail are not plotted. Only 1915 tests are available for the Pacific Locomotive on the 85-lb. rail; in comparing with the bending moment coefficients for the 125-lb. rail from the 1916 tests it should be kept in mind that the 1915 values are probably somewhat low. For convenience in comparing results lines have been drawn connecting corresponding points.

The upper left-hand diagram of Fig. 119 gives values of the bending moment coefficient for the one-axle load tests with the three rail sections. In the static load tests as readings were taken on only one side of the rail except in the 1917 tests, the values may not be directly comparable though for this form of test not much variation has been found for the two sides of the rail. It is seen that the heavier rail gives a much higher bending moment coefficient than the lighter. If the difference in the track conditions be taken into account, the 125-lb. rail being on track of 24-in. ballast which gave a higher modulus of elasticity of rail-support than that of the track on which the tests of 85-lb. rail here used were made, the contrast becomes greater. Fig. 119 also gives the analytical values of the bending moment coefficients for a one-axle load based on the probable values of the modulus of elasticity of rail-support used in the tests, 1000 in one case and 1600 in the other. The trend of the analytical values is much the same as that derived from the test data.

The upper right-hand diagram of Fig. 119 gives values of the bending moment coefficient corresponding to the observed stress found in the three rail sections for the two-axle load tests. The wheel spacing is 66 in. The analytical values of the bending moment coefficients are also given. The same values of the modulus of elasticity of rail-support are used as for the one-axle load tests. The trend of the values shows higher bending moment coefficients for the heavier rail sections.

Fig. 119 also gives values of the bending moment coefficients corresponding to the stresses observed in the moving load tests with the Mikado, Atlantic and Pacific locomotives. Values are given for speeds of 5 miles per hour and 35 or 60 miles per hour. The bending moment coefficients for the heavier rail sections are markedly larger than for the lighter sections, and this is true for the drivers and the trailer. The values of the coefficients of negative bending moment are not plotted here, but these also show an increased coefficient for the heavier rail sections. That the bending moment coefficients should be greater for the heavier sections is evident from analytical considerations, especially in the case of the trailer, which is at some distance from other wheels and in the case of outer drivers. The increase due to increase of section, however, is greater than may be expected from the analysis of track action herein given, or for any known rational analysis. For the drivers and trailer of the three types of locomotive used on the Illinois Central Railroad the values of the bending moment coefficient derived by the analysis are less than 10 per cent. higher for track with the 125-lb. section than for track with the 85-lb. section. For the tests at 5 miles per hour the values of the bending moment coefficients average nearly 30 per cent. higher with the 125-lb. section than with the 85-lb. section, considering the drivers and the trailer of the three types of locomotive. For the tests at the higher speeds the increase is still greater.

In Fig. 119 also are plotted points for the bending moment coefficients derived from the tests on the Delaware, Lackawanna & Western Railroad with the Mikado and Pacific locomotives, the rail being 105-lb. section. The wheel spacing and wheel loads in these locomotives are, of course, not the same as those of the same type on the Illinois Central Railroad.

51. *Effect of Wheel Spacing.*—The analytical treatment of the action of track showed that the spacing of wheels has a considerable effect upon the magnitude of the bending moments developed in the rail. The experimental values confirm this finding. An inspection of Fig. 119 shows that for all the locomotives, except the Atlantic, the bending moment coefficients for the trailers, which are well away from the drivers and the tender trucks, are considerably higher than those for the drivers, and that those for the drivers of the Atlantic locomotive are higher than for the more closely spaced drivers of the Mikado locomotive. The effect is even more marked at the higher speeds. Another view of this may be had from the stresses plotted in Fig. 118. Notwithstanding that the weight on the trailer of these locomotives in only 75 per cent. to 80 per cent. of that on a driver, the stresses in the rail under the trailer are greater than those under the drivers except for the Atlantic locomotive, and in the case of the Atlantic there is greater spacing of drivers and smaller distance from the rear driver to trailer. All the results confirm the importance of wheel spacing indicated by the analysis.

Something of the effect of changing the spacing of wheels is shown by Figs. 120, 121 and 122, where values of the bending moment coefficients derived by the analytical method are plotted against wheel spacing for two-axle loads, three-axle loads and four-axle loads. In some cases it is seen there are regions of spacing where the spacing has little effect upon the bending moment coefficient. It is to be noted that for a point midway between wheels the shorter spacings give positive moments. Although the values given in this figure will not correspond exactly with experimental results, the figure is useful in learning the trend of the effect of changes in wheel spacing. It is evident that the effect of wheel spacing upon stresses in track is a matter which should have consideration when the design of the spacing of the wheels of locomotives and cars is made.

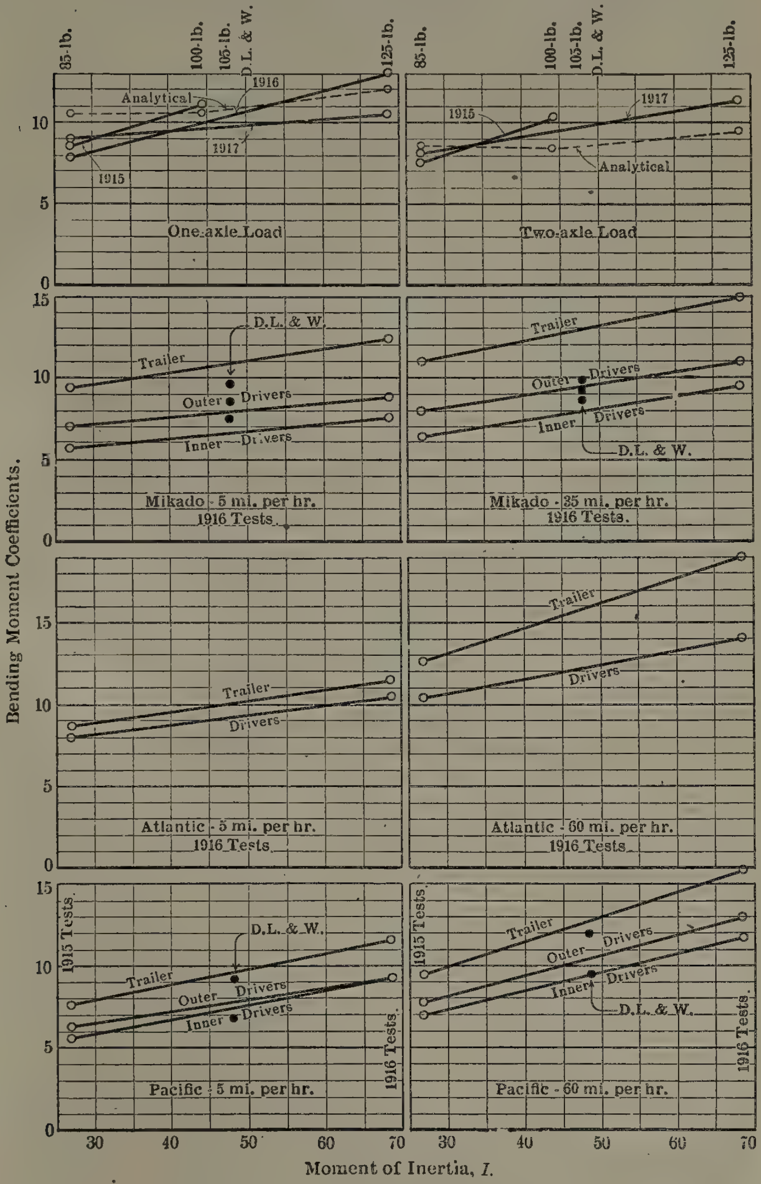

BENDING MOMENT COEFFICIENTS FOR THREE RAIL SECTIONS.

FIG. 119.

52. *Influence of Condition of Track and Locomotive.*—The tests already reported are mainly on the prepared test sections of track which were laid with new oak ties of uniform size and shape, uniformly spaced and kept in excellent surface condition. It was felt that some connection of results should be made with track in conditions other than those of the prepared track, and tests were made on what may be considered the ordinary run of main line track adjoining the test sections and on track having special conditions, such as low spots, defective ties and cinder ballast.

The tests on what may be termed the ordinary track of the Illinois Central Railroad were made on track adjacent to the test sections of track. The conditions of rail, ballast and roadway were quite similar to those of the prepared test sections. The ties were sound hewn ties of mixed woods, oak and gum and some pine, nominally 6 x 8 in. x 8 ft., spaced fairly uniformly about 20 in., center to center. The tests were made on stretches of track having 6 in. and 24 in. of ballast under the ties. The track was in good condition. Fig. 123 gives track depression profiles for one-axle load tests at three locations. The data were obtained photographically and cover only a short length of track for each location. Fig. 124 shows the stress distribution diagrams at the same places, and Fig. 125 gives load-stress diagrams. It will be noted that the load-stress diagrams approximate straight lines passing through the origin. Figs. 126 and 127 give speed-stress diagrams for locomotive loading at several speeds at two places along the track. The position of instruments and the methods used were the same as in the tests reported for the test track. The average value of the modulus of elasticity of rail-support, *u*, taken from the one-axle load tests is about 1000, which is about the same as the average for the special tests sections (omitting the 24-in. ballast). The stresses in rail, both for the one-axle load tests and the moving-load tests, agree closely with the results found in the similar tests on the prepared test stretches of track of like conditions of ballast and rail, the differences being no more than may be due to accidental differences in the locomotive or to accidental differences in testing. The results indicate that the tests on the prepared sections of track may be taken as representative of similar track under ordinarily good conditions and that the principal difference to be expected in ordinary track is a greater variation in results and somewhat larger individual values where differences in tamping or in size or quality or spacing of tie may result in a greater variation from the average stress.

To get some indication of the effect of a poor tie, tests were made in several places where a tie under one rail was decayed somewhat and the rail had cut into the adjoining ties, the decayed tie not taking its full share of load and the adjoining ties having more than their share. Fig. 128 gives track depression profiles for the one-axle load tests at three locations, *E. F* and *G*, of Fig. 26, the load being placed

BENDING MOMENT COEFFICIENTS FOR TWO-AXLE LOAD, FROM ANALYSIS.

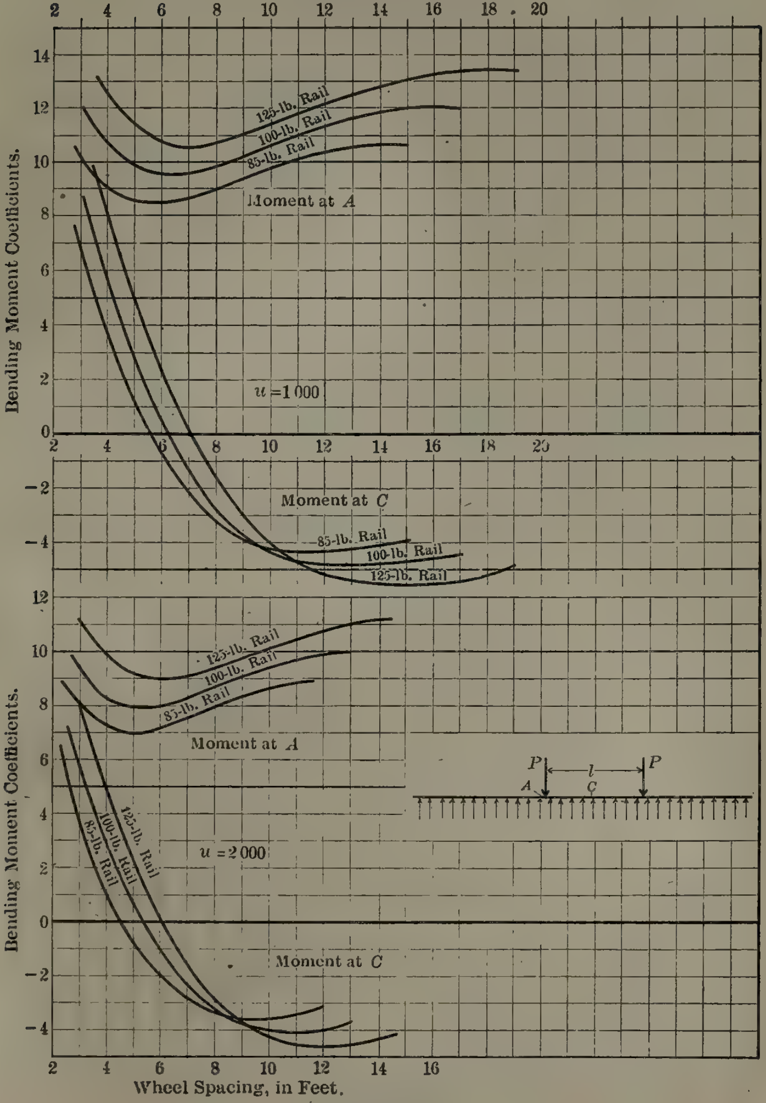


FIG. 120.

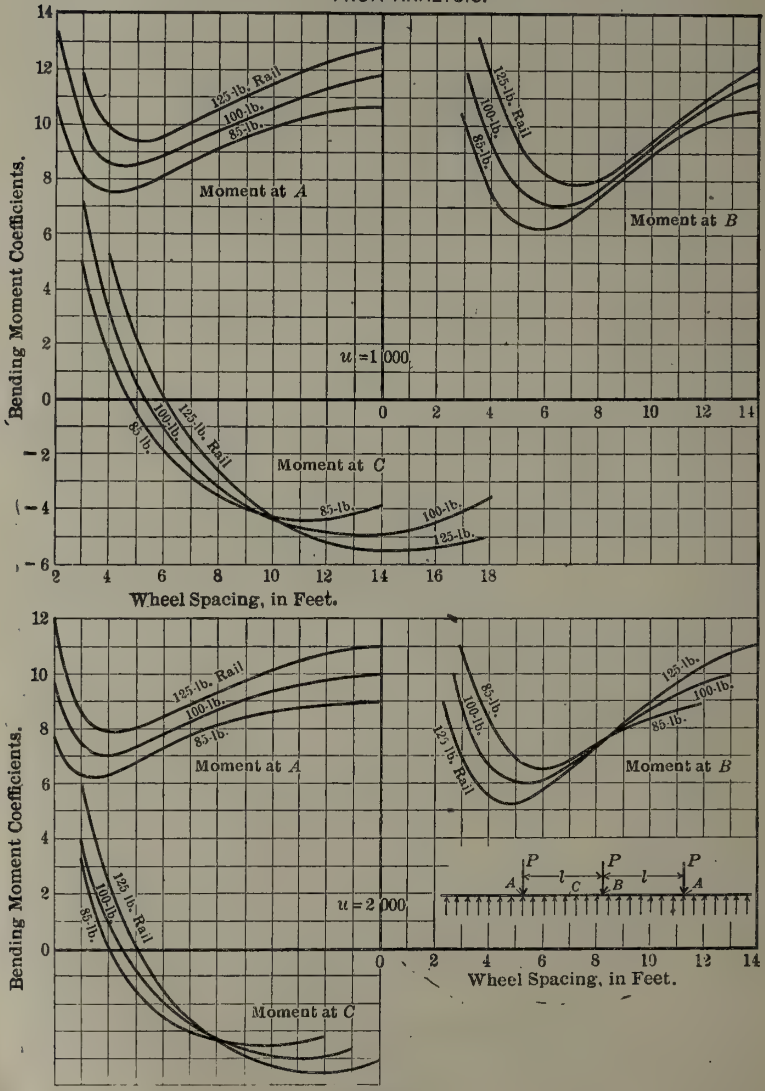

BENDING MOMENT COEFFICIENTS FOR THREE-AXLE LOAD, FROM ANALYSIS.

FIG. 121

BENDING MOMENT COEFFICIENTS FOR FOUR-AXLE LOAD,
FROM ANALYSIS.

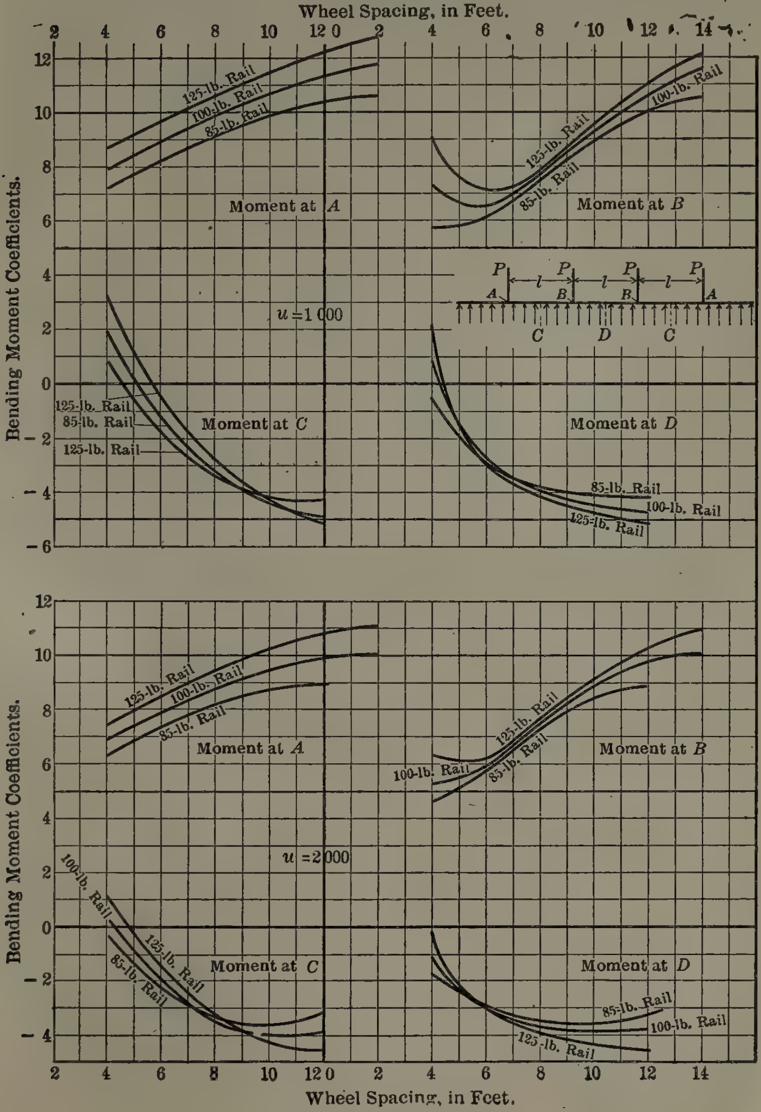


FIG. 122.

over the decayed tie. The profiles are characterized by a sharper curvature at the point under the load than was found in the tests with sound ties, though the depression was not particularly greater than in ordinary track. Fig. 129 shows the stress distribution diagrams at the same places, and Fig. 130 gives load-stress diagrams. In some cases the load-stress diagram is a straight line passing through the origin and in some cases not. The stresses in the rail over the decayed tie for a single-wheel load of 25,000 lbs. are 23,800, 25,600, 29,200 lbs. per sq. in. (averaging 26,200 lbs. per sq. in.), which may be compared with an average stress of about 21,000 lbs. per sq. in. for otherwise like conditions of track in the prepared test sections. Moving-load tests with the Mikado locomotive were also made at the two locations, *I* and *L*, shown in Fig. 26. Fig. 131 gives the position of the instruments with reference to the decayed tie, and Figs. 132 and 133 are speed-stress diagrams giving the average of the stresses obtained with three instruments. At location *I*, the decayed tie was in such condition that it gave little bearing resistance to the rail load, and the two adjoining ties were sound but somewhat cut by the rail. At location *L*, the decayed tie offered some bearing resistance, but the adjacent ties were poor and badly cut. Comparing the stresses in the rail given in these figures with the average stresses for the prepared test sections, it is seen that the stresses under the drivers and trailer of the Mikado locomotive at the several speeds from 5 to 35 miles per hour average about 20 per cent. higher in the first location and 35 per cent. to 40 per cent. higher in the second. As these stresses were measured at gage lines between ties and include measurements made at places away from the decayed tie, it may be expected that the stress in the rail at a point over the decayed tie would be materially higher than that given in the diagrams. It will be shown in the next article that the variation in stress on the two sides of the rail is much greater in this case than in ordinarily good track. Stresses at the outer edge of base of rail were found which average about 150 per cent. higher than the average rail stress for good track.

Tests were made on a spot where for about a rail length the track was low, especially along one rail. A low spot on the other rail a rail length or so away served to give the locomotive a roll at speeds above 5 miles per hour. The sags were quite apparent to the eye. The section foreman explained the presence of the low spots as caused by too much tamping at the ends of the rail in raising the joints which had become low. The track depression throughout the middle of the length of the rail under the static-load tests was 0.70 in. under the rear driver of the Atlantic locomotive, about double that found after the track had been properly tamped up, the latter being about the same as that which was found in ordinarily good track. Figs. 134 to 136 give the speed-stress diagrams for the Atlantic locomotive at this low spot. The number of observations is smaller than have been averaged in the tests

TRACK DEPRESSION PROFILES FOR DECAYED TIE.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD, WITH LOADING APPARATUS.

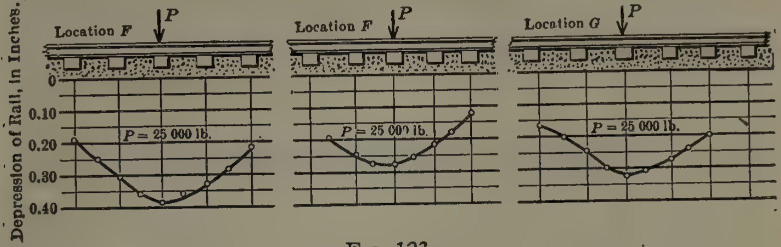


FIG. 123.

STRESS DISTRIBUTION DIAGRAMS FOR ORDINARY TRACK.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD,
WITH LOADING APPARATUS.

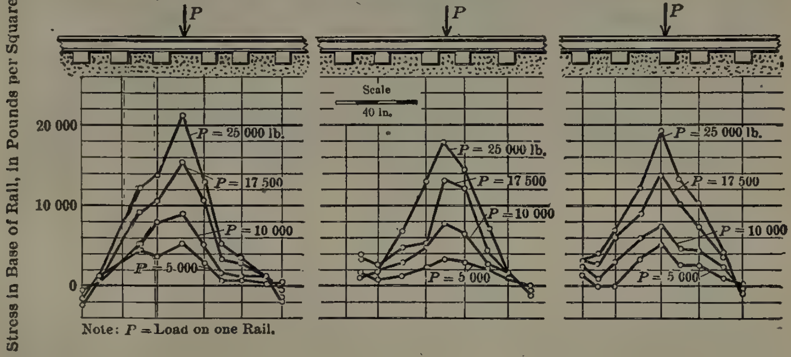


FIG. 124.

LOAD-STRESS DIAGRAMS FOR ORDINARY TRACK.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD, WITH LOADING APPARATUS.

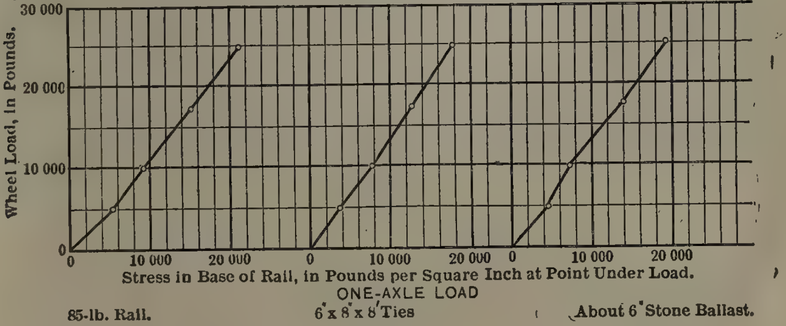


FIG. 125.

SPEED-STRESS DIAGRAMS FOR ORDINARY TRACK
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

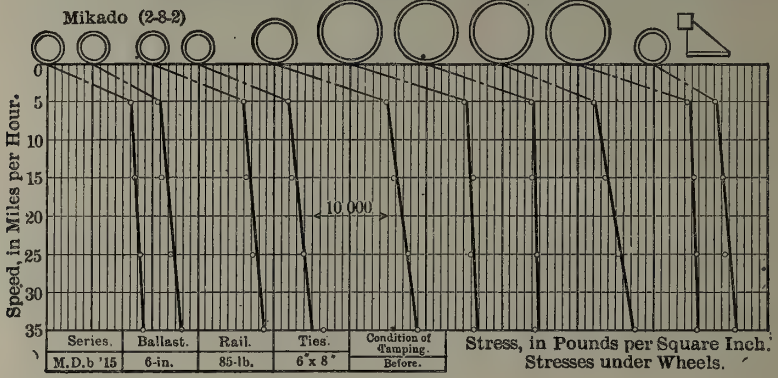


Fig. 126-a.

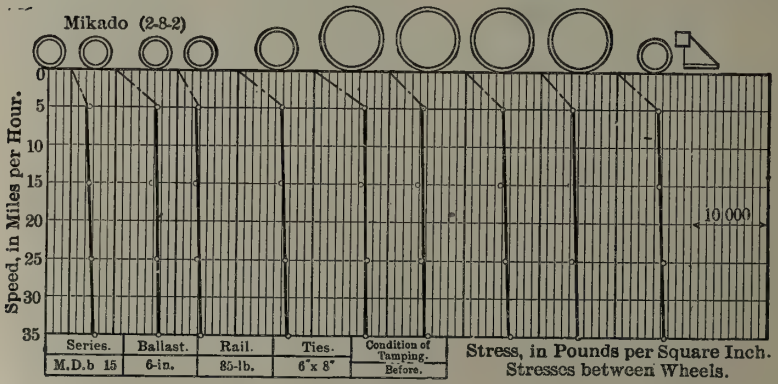


Fig. 126-b.

SPEED-STRESS DIAGRAMS FOR ORDINARY TRACK
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.

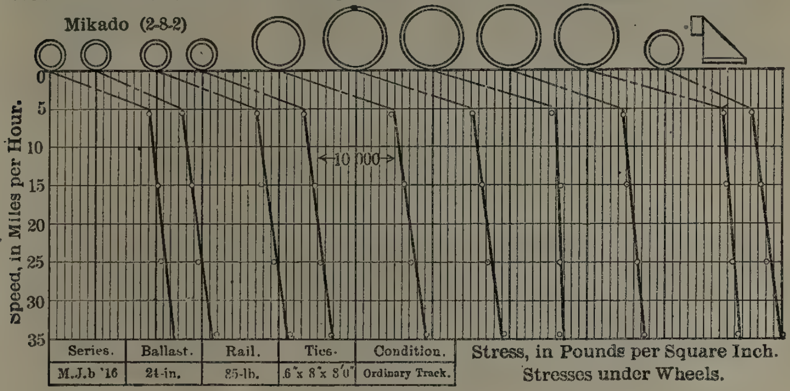


FIG. 127-a.

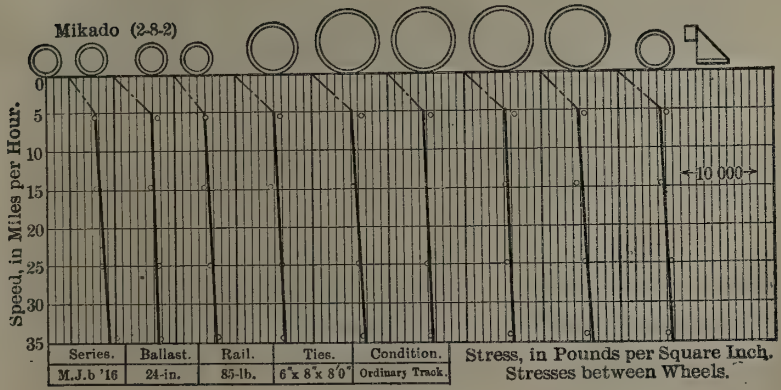


FIG. 127-b.

TRACK DEPRESSION PROFILES FOR ORDINARY TRACK.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD,
WITH LOADING APPARATUS.

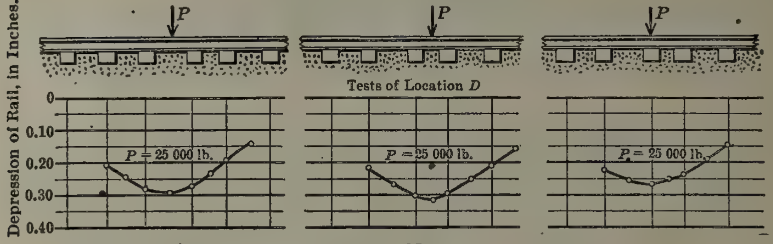
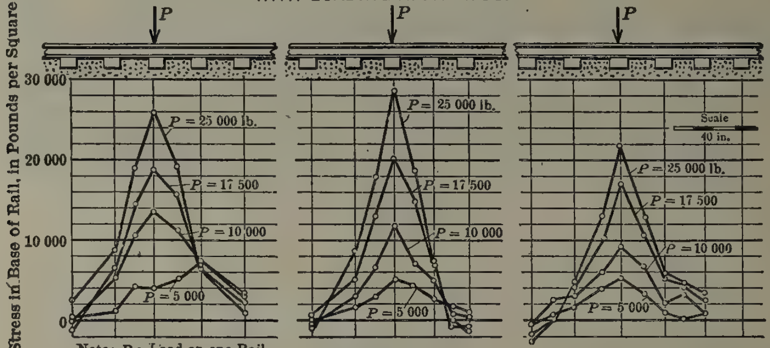


FIG. 128.

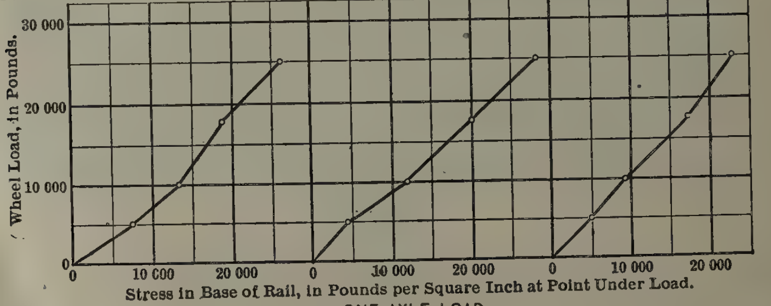
STRESS DISTRIBUTION DIAGRAMS FOR DECAYED TIE.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD,
WITH LOADING APPARATUS.



Note: P = Load on one Rail.

FIG. 129.

LOAD-STRESS DIAGRAMS FOR DECAYED TIE.
STATIC-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD, WITH LOADING APPARATUS.



ONE-AXLE LOAD

85-lb. Rail. 6"x 8"x 8' Ties About 6" Stone Ballast.

FIG. 130.

on the prepared stretches of track, but it is large enough to seem to be representative of the action of the track here. At 5 miles per hour the stress in rail is about 15 per cent. higher than for good track, and at 60 miles an hour, 20 per cent. to 35 per cent. higher. At the latter speed values at the front driver were found as high as 43 per cent. more than for good track. In each case the values plotted are the averages of the values obtained with the three instruments on the low rail for three or more runs.

Tests were made on the track which leads from the freight yards at location *N* in Fig. 26. This track has 6 in. of cinder ballast on a light loam soil. The ties were in good condition and the tie spacing uniform. Although not recently tamped, the track was in fair condition. Fig. 137 gives the speed-stress diagrams for the Mikado locomotive. The stresses are higher than those found with 6 in. of ballast on the main-line track, averaging perhaps 12 per cent. higher, and, under some wheels, being 18 per cent. or more higher. A rather marked characteristic of these diagrams is the unusual variation in values at the different wheels and the different speeds; individual results are found which are much higher than the average values which are plotted in the diagrams.

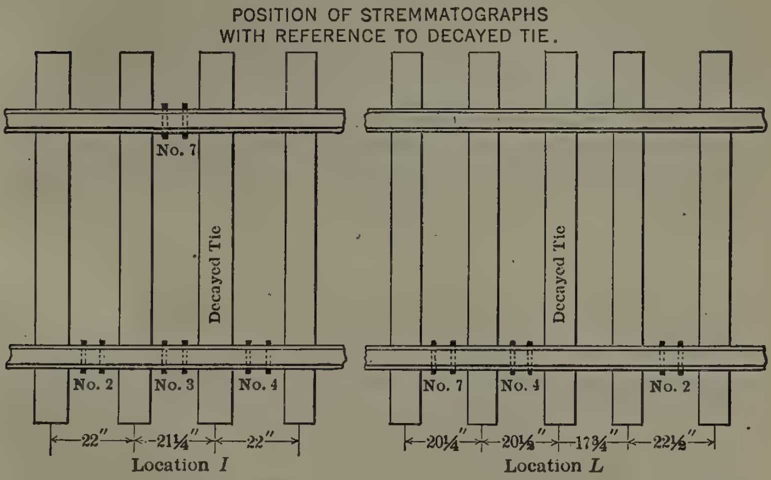
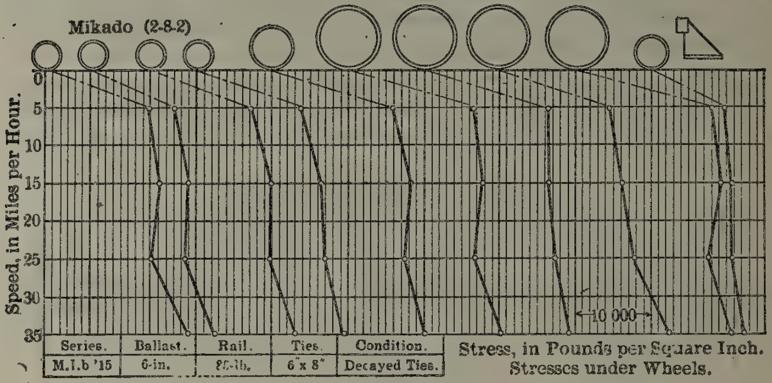


FIG. 131.

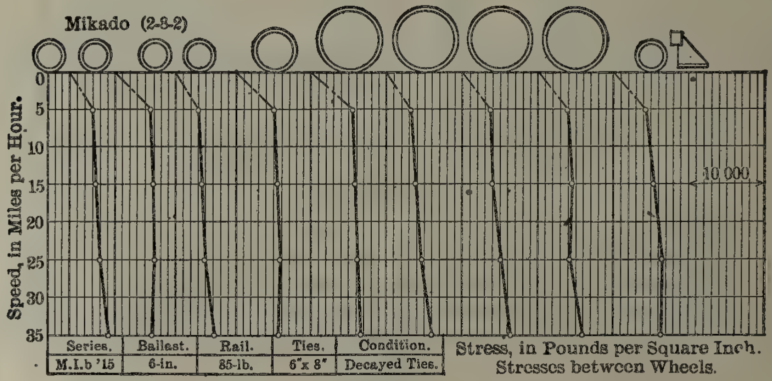
Although this report will not take up the observed action of the ties and ballast and the relation of their properties to the properties of the track, it may be remarked here that the prepared main-line test track, which is ballasted with broken stone, seems to show little difference between the stresses in rail on track which has 6 in. of ballast and on track which has 12 in. The results are more erratic and more variable in the former case than in the latter, and of course the ques-

SPEED-STRESS DIAGRAMS FOR DECAYED TIE.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE



Series.	Ballast.	Rail.	Ties.	Condition.
M.I.b '15	6-in.	85-lb.	6"x 8"	Decayed Ties.

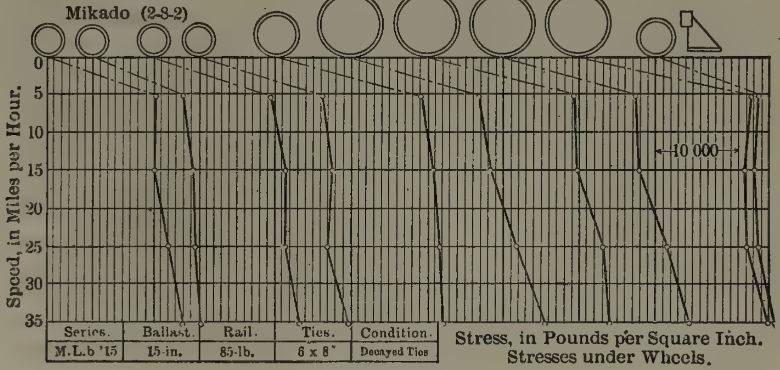
FIG. 132-a.



Series.	Ballast.	Rail.	Ties.	Condition.
M.I.b '15	6-in.	85-lb.	6"x 8"	Decayed Ties.

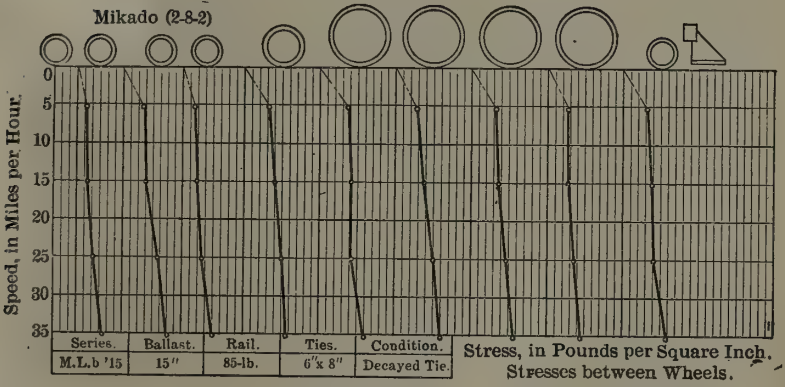
FIG. 132-b.

SPEED-STRESS DIAGRAMS FOR DECAYED TIE.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.



Series.	Ballast.	Rail.	Ties.	Condition.
M.L.b '15	15-in.	85-lb.	6 x 8"	Decayed Ties

FIG. 133-a.



Series.	Ballast.	Rail.	Ties.	Condition.
M.L.b '15	15"	85-lb.	6"x 8"	Decayed Tie.

FIG. 133-b.

tion of the time intervals between necessary track surfacing is not here considered. The track with 24-in. ballast was noticeably stiffer than either of the foregoing, giving smaller track depressions under load and a larger value of the modulus of elasticity of rail-support. The diagrams also show that the track on 24-in. ballast has somewhat smaller stress in the rail than the track on lighter ballast.

To show that conditions of the locomotive may greatly affect the amount and distribution of the stresses in the rail, an instance which occurred in one of the early tests may be cited. A test was being made to compare the results obtained by the strain gage and the stremmatograph. The stremmatograph record showed almost no stress under the third driver of the Mikado locomotive. Strain-gage readings made with static loading gave the same results. An examination showed that the equalizer for the third driver had been temporarily blocked up by the engineman while out on a run to decrease the load on the driver to prevent heating of the bearing and the blocking had not been removed when the locomotive was returned to the roundhouse. In Fig. 138 are given the stresses under the wheels obtained by strain-gage measurements when the equalizer was blocked up, and also the values obtained with the locomotive in normal condition. It is seen that the stress under the fourth driver was greatly increased and that those under the second driver and the trailer were somewhat larger than for normal conditions.

53. *Relation of the Stresses on the Two Sides of the Rail.*—It may appear natural to think that, since the wheel load is a vertical load, the flexural action in the rail will be such that the fiber stress will be uniform all the way across the base of the rail. Even if the pressure of the wheel is not applied centrally over the head of the rail the effects of this eccentricity of loading will be to produce vertical flexural stresses in the rail and probably a torsional effect; little lateral horizontal bending of the rail may be expected to result from this source. In planning the tests lateral bending of the rail was not expected to be an important element. In the earlier test work, therefore, the strain measurements with both the strain gage and the stremmatograph were made at one edge of the base of the rail only, the outer edge being used because of its greater convenience. The stremmatograph tests showed marked irregularities and seemingly erratic results, which were unexplainable on the ordinary assumption, and steps were taken to find the source of the variations. Tests were made with the position of the stremmatograph reversed on the rail in order to measure the deformation at the inner edge, and the results were compared with those found with the measurements at the outer edge of the rail, all other conditions as to track, position of locomotive and speed remaining the same. The average of the stremmatograph measurements at the two edges of the base of rail was found to be fairly uniform and consistent for runs which were comparable, but the stress at one edge was

SPEED-STRESS DIAGRAMS FOR LOW SPOT IN TRACK.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD.
WITH ATLANTIC LOCOMOTIVE.

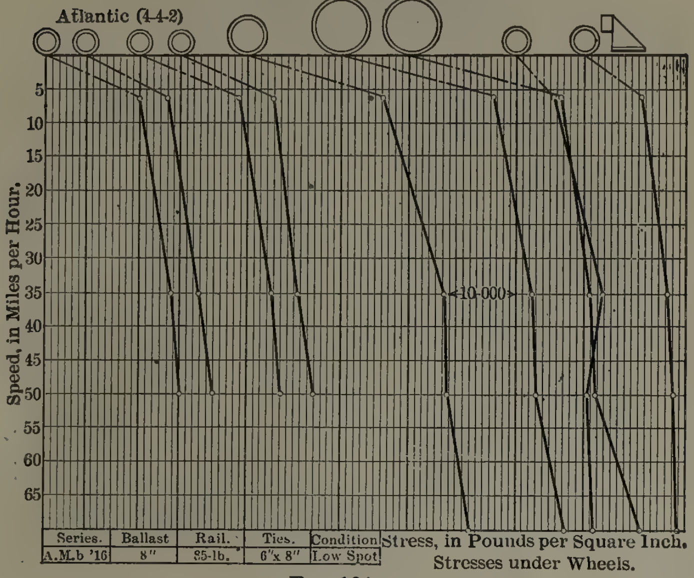


FIG. 134-a.

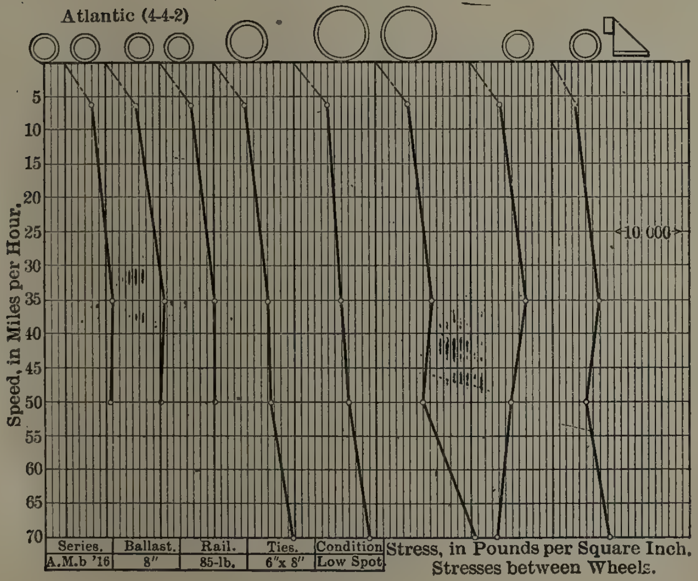


FIG. 134-b.

SPEED-STRESS DIAGRAMS FOR LOW SPOT IN TRACK.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD,
WITH ATLANTIC LOCOMOTIVE.

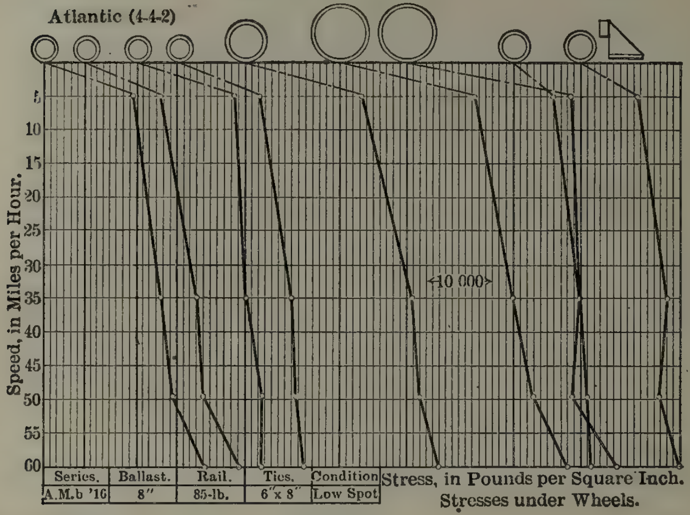


FIG. 135-a.

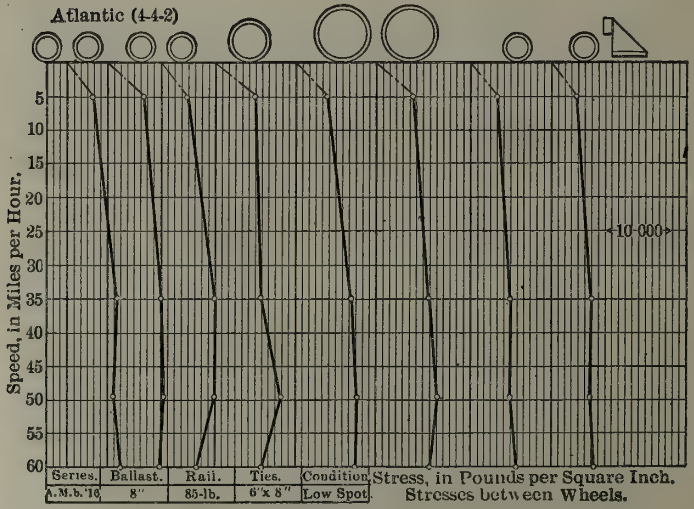


FIG. 135-b.

SPEED-STRESS DIAGRAMS FOR LOW SPOT IN TRACK.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD.
WITH ATLANTIC LOCOMOTIVE.

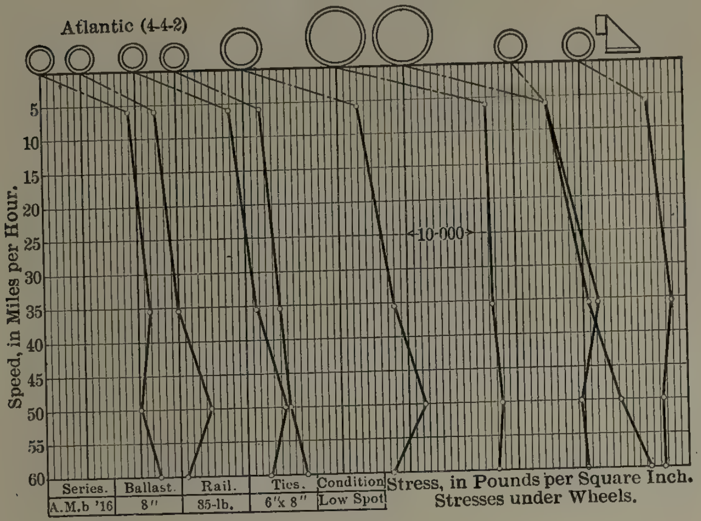


Fig. 136-a.

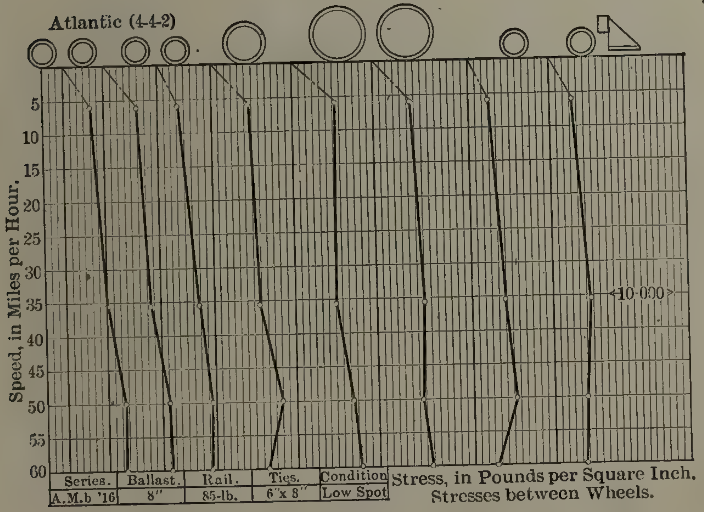


Fig. 136-b.

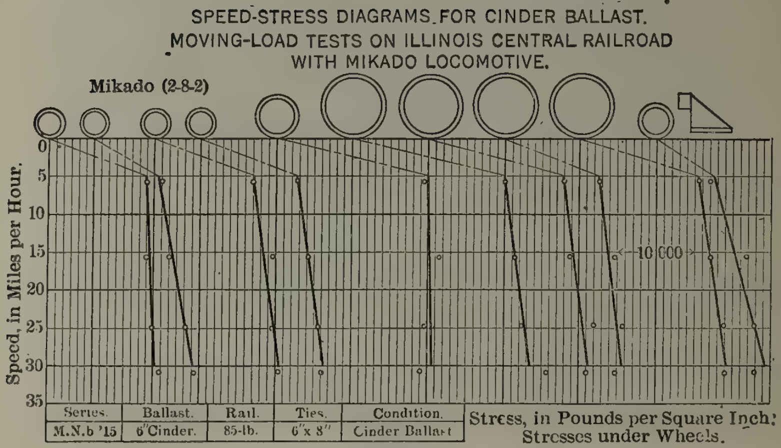


Fig. 137-a.

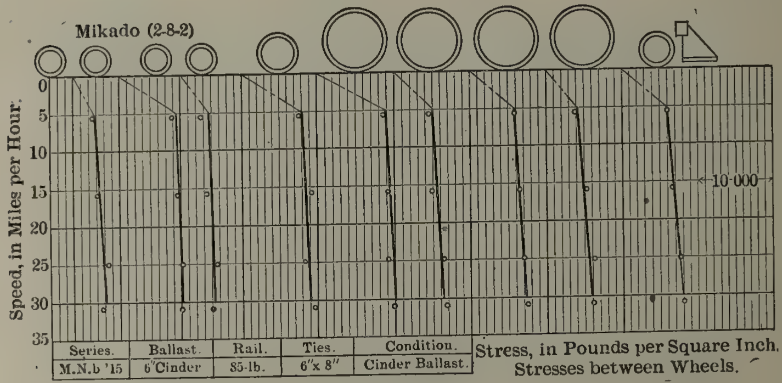


Fig. 137-b.

usually different from that at the other edge, sometimes more than twice as great. Generally speaking, the higher value was found at the outer edge of the rail. The instruments already made were then rebuilt in such way that each stremmatograph measured the deformation both at the inner edge of the base of rail and at the outer edge, and this improvement was followed in instruments made thereafter. It may be added that in static tests with a locomotive the results of measurements made with a strain gage showed differences in stresses at the two edges which were quite similar to the results found in the moving-load tests, while static tests made with the loading device showed little difference in stress on the two sides of the rail.

As another check on the phenomenon, measurements were made at the base of the rail to see whether the rail showed lateral movement as the wheel moved by. It was observed that there was an outward movement at the base of the rail immediately under the wheel and an inward movement at a point between wheels, the rail thus forming along the length of the locomotive a horizontal curve something like a sinusoid. A similar outward and inward movement occurred in the other rail, and, in the observations referred to, the movements of both rails were outward under a given axle and inward at points between axles; in other words, the gage of the base of rail was increased at the wheel points and decreased at points between wheels. The amount of this movement was small, but it was measurable, ranging from 0.01 in. to 0.03 in. with the 85-lb. rail in the preliminary test referred to. It will be seen later that the movement of the rail is not always of the character just described, there being several forms of movement.

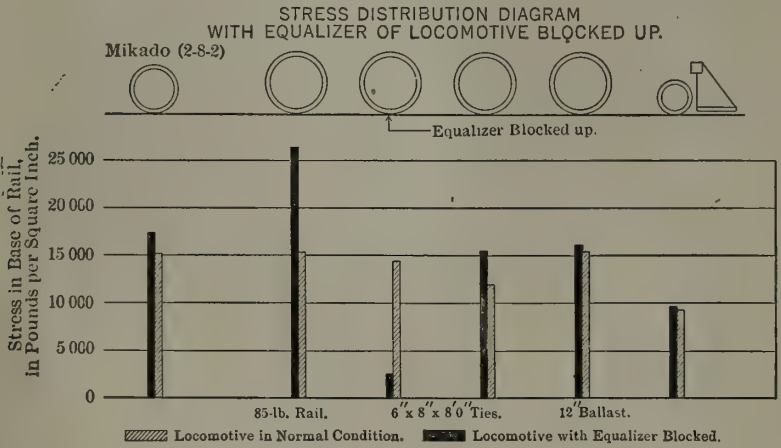


FIG. 138.

With an outward bending of the rail at a point under a wheel load the tensile stress at the outer edge of the base of rail is increased over that due to vertical bending, and with an inward bending at a point between wheels the compressive stress at the outer edge of the base of rail is also increased, the stress at the inner edge of rail being decreased in both cases. In the head of the rail the effect on the stresses is reversed, but since the head is narrower than the base the difference in stresses at the two sides of the head of the rail is smaller than that found at the base of the rail.

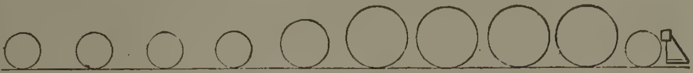
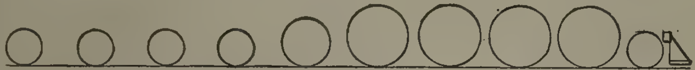
Table 10 gives values of the ratio of the stress at one edge of the base of rail to the mean of the stresses at the two edges. Where the minus sign is given, the stress at the inner edge is the greater; otherwise that at the outer edge is the greater. The table is a sample of the data obtained (the complete data being very voluminous) and is probably representative of the observations. The values given are those found by individual instruments; averages of several instruments would mask the effect of variations in track and of variations in movement of locomotive. In looking over the table it should be borne in mind that the runs were made in a way such that the counterweight of the front driver on the side of the track on which there were three instruments was at its lowest point as it passed the middle instrument, and that the succeeding wheels made their records at a later time, and therefore the measurement of stresses for the several wheels was not made simultaneously. Naturally the values cover quite a range. There are many ratios as high as 1.30 and a number as great as 1.50 (which means that the stress at one edge of base is 1.86 and three times as great, respectively, as the stress at the other edge). The few ratios higher than 1.75 doubtless may not be fully reliable.

The ratios at points midway between wheels (not given in the table) run to even higher values and are more discordant, as might be expected, from the fact that the magnitude of the stress is less than that at points under the wheels. The difference between the numerical value of the stresses at the two edges, as may be expected, is in general less at the point between wheels than it is at points under the wheels.

The phenomenon of difference in stress at the two sides of the rail is found at all speeds. The magnitude of the stress at either edge of the base of rail varies with the speed, generally increasing with increase of speed, though sometimes the stress at one edge decreases with speed. In general, the ratio of the stresses at the two edges of the base of rail is not noticeably different at high speeds than at low. In fact, the changes in stress with speed are quite consistent at each edge, as is shown in Fig. 139.

It appears that one of the elements which affect the differences in stresses developed at the two edges of the base of rail is the condition of the track. Higher ratios are found more frequently in track not recently tamped. An excellent example of the effect of the condition of track is seen in the observations at the two locations having a tie in the partially decayed condition referred to in article 52. The position

TABLE 10.—VALUES OF THE RATIO OF THE STRESS AT ONE EDGE OF THE BASE OF RAIL TO THE MEAN OF THE STRESSES AT THE TWO EDGES. PREPARED TEST SECTIONS OF TRACK.

Speed, in miles per hour.	Instrument No.	85-Lb. Rail			6-In. × 8-In. × 8-Ft. Ties				12-In. Stone Ballast		
											
5	2	1.12	1.16	1.10	1.15	1.09	1.10	1.18	1.16	1.13	1.05
	3	1.13	1.07	1.05	1.11	1.05	1.00	1.02	— 1.04	1.03	1.06
	4	— 1.03	1.04	1.03	1.11	1.04	1.09	1.08	1.08	1.00	1.01
	7	— 1.18	1.10	1.09	1.15	1.02	1.07	1.10	1.02	1.09	— 1.07
15	2	1.11	1.06	1.05	1.13	1.10	1.08	1.15	1.12	1.08	1.04
	3	1.02	— 1.02	— 1.01	1.07	— 1.01	1.02	1.07	— 1.04	— 1.01	— 1.05
	4	1.12	1.09	1.07	1.13	1.04	1.09	1.11	1.02	1.07	1.01
	7	1.07	1.07	1.04	1.17	1.05	1.10	1.11	1.02	1.07	— 1.14
25	2	1.13	1.11	1.07	1.19	1.12	1.02	1.10	1.08	1.11	— 1.07
	3	1.05	1.03	— 1.05	1.00	— 1.08	— 1.04	1.10	— 1.08	1.01	— 1.09
	4	1.12	1.10	1.10	1.13	1.07	1.02	1.07	1.09	1.03	1.08
	7	1.09	1.01	1.17	1.10	1.00	1.05	1.05	1.07	1.05	— 1.07
35	2	1.01	1.05	1.00	1.00	1.04	1.06	1.04	1.05	1.18	— 1.15
	3	1.03	— 1.02	— 1.01	1.03	1.00	— 1.06	— 1.05	1.02	— 1.01	— 1.06
	4	1.10	— 1.11	1.07	1.04	1.01	— 1.02	1.05	— 1.01	1.00	— 1.02
	7	1.05	1.04	1.09	1.05	1.07	— 1.02	1.11	— 1.06	1.02	1.00
Speed, in miles per hour.	Instrument No.	125-Lb. Rail			6-In. × 8-In. × 8-Ft. Ties				24-In. Stone Ballast		
											
5	8	1.15	1.11	1.18	1.09	1.14	1.12	1.11	1.05	1.20	1.14
	9	1.10	1.10	1.02	1.14	1.13	1.11	1.20	1.17	1.11	1.09
	11	1.07	1.09	1.05	1.15	1.14	1.14	1.26	1.23	1.13	1.13
	12	1.05	1.05	1.09	1.21	1.20	1.22	1.25	1.22	1.25	1.12
15	8	1.08	1.05	1.10	1.04	1.07	1.05	1.06	1.03	1.09	— 1.01
	9	1.11	1.09	1.01	1.13	1.10	1.12	1.26	1.15	1.15	1.13
	11	1.07	1.05	1.02	1.12	1.15	1.19	1.30	1.24	1.19	1.20
	12	1.17	1.11	1.24	1.22	1.24	1.16	1.37	1.32	1.31	1.15
25	8	1.07	1.02	1.02	— 1.02	1.02	1.07	— 1.02	1.06	— 1.03	— 1.01
	9	1.13	1.12	1.04	1.18	1.10	1.09	1.26	1.25	1.19	1.13
	11	1.12	1.12	1.06	1.16	1.10	1.11	1.23	1.19	1.24	1.13
	12	1.25	1.22	1.13	1.24	1.11	1.19	1.17	1.20	1.23	1.12
85	8	— 1.03	— 1.06	1.06	— 1.03	— 1.01	— 1.07	— 1.07	1.00	— 1.10	1.03
	9	1.09	1.06	1.03	1.09	1.07	1.04	1.25	1.15	1.09	1.04
	11	1.12	1.12	1.06	1.15	1.08	1.10	1.15	1.07	1.12	1.11
	12	1.10	1.08	1.14	1.20	1.10	1.22	1.11	1.22	1.17	1.28

of the instruments with reference to the poor tie is shown in Fig. 131. The ratio of the stress at edge of rail to the mean of the stresses at the two edges is given in Table 11. Each value given for a single instrument is the average of the results at several runs at a given speed; individual runs give higher ratios. In the test at location I, Fig. 26, for instrument No. 2, which was next to the decayed tie, the average of the ratios under the drivers and trailer for all speeds is 1.35 (about 80 readings in all). The average of the highest values found at each speed for all the drivers and trailer is 1.46 (about 16 readings included in getting this average). Stated in the other way, this means that the stress at the outer edge of the base of rail is about 2.1 times the stress at the inner edge when the ratio is 1.35, and 2.7 times when the ratio is 1.46. For instrument No. 3, located at the tie space ahead of No. 2, the average ratio at all speeds is 1.26, the highest being 1.36. For instrument No. 7, which is on the other rail and opposite instrument No. 3 (this end of the decayed tie being sound), the variation in stresses is the same as at No. 3 (i. e., the rail bends outward); the average of the ratios at all speeds is 1.10, with a maximum ratio of 1.14. For instrument No. 4, ahead of No. 3 and on the other side of the decayed tie, the ratio is 1.16 and runs sometimes positive and sometimes negative. For this instrument, the ratios given by the records at the time the instrument was midway between wheels are high, the average for all the wheels and all the runs being 1.48, with maximum values of 1.67.

In the case of the other test location at a partially decayed tie (location *L*, Fig. 26), the instruments were placed on one rail only. The values in Table 11 show highest values for instrument No. 7, although instrument No. 4 gives nearly as high an average. One driver gives an average ratio at all speeds of 1.43, with a maximum of 1.50 at one speed.

High ratios of the stress at the edge of base of rail to the mean of the stresses at the two edges were found in the case of track ballasted with cinders. This track (location *N*, Fig. 26), was not in as good surface and alinement as the main-line track. Table 12 gives the ratios under the drivers and trailer at the several speeds. It is seen that ratios as high as 1.35 were not infrequent. In Fig. 140 the stresses at the two edges of the rail, found by averaging the results from the four instruments, are shown for the four speeds used. It is seen that for each wheel the stress at one edge of the base of rail is in general consistently larger than at the other. The averages of all the instruments at 30 miles per hour give stresses of 31,000 lbs. and the records of individual instruments were as high as 35,000 lbs. (the latter being, of course, the average of several runs).

Some high values of ratios found on the prepared test track when in good condition are given in Table 13, which gives the results of a single run with a Mikado locomotive at a speed of 35 miles per hour.

It is seen that at instrument No. 4 all wheels except one give high ratios, the highest being 1.75 (the stress at the outer edge in this case being 35,000 lbs. per sq. in. and that at the inner edge 5,000 lbs. per sq. in.). At instrument No. 2, the stresses at the inner edge usually are higher than those at the outer edge.

A study of the data, including a large amount not here reported, shows that the stress at the outer edge of base of rail is almost always larger than that at the inner edge, and also that, generally, both rails bend outward under the wheel loads. Sometimes one rail bends inward as the other bends outward, indicating a swing of the load. Generally the bending is inward at a point between wheels, but sometimes it is in the reverse direction. To what extent the coning of the wheels contributes to the outward bending of the rail and what other factors enter into the action will not be discussed in this report. In this connection it should be noted that for the tests with the loading jacks very little difference was found in the stresses at the two sides of the rail.

SPEED-STRESS DIAGRAM FOR EACH EDGE OF BASE OF RAIL.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVI

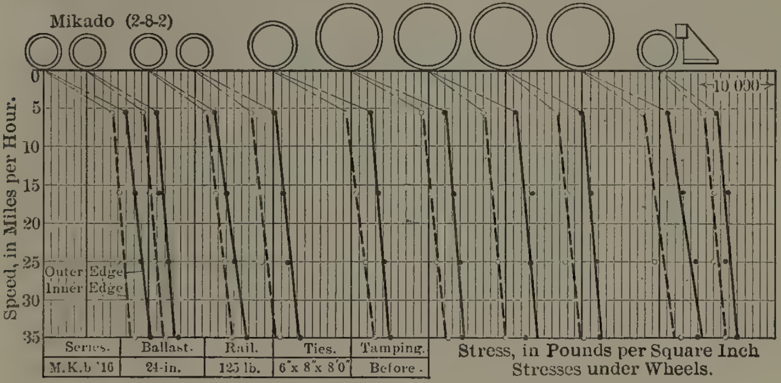
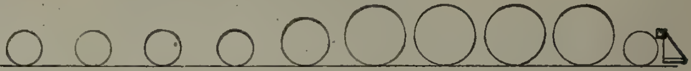


FIG. 139.

It seems evident from a study of all the data that stresses at the edge of base of rail 30 per cent. greater than those due to vertical load may be expected in what would be considered good track and that occasional values considerably higher than 30 per cent. are probable. With track in poor condition, the lateral bending of rail is even greater. This means that the lateral strength of the rail is an important element in track resistance. For the various rail sections used, the section modulus $(\frac{I}{c})$ with reference to a vertical axis averages about 23/100 of that for a horizontal axis. The lateral bending moment, then, is much less than the vertical bending moment, but its effect in increasing the fiber stress is such that it needs consideration in the determination of stresses in rail.

54. *Variation in Measured Stresses and the Relation Between Average Stress and Maximum Stress.*—The stress developed in the rail under moving loads applied through locomotive and car wheels may not be expected to have the same magnitude for different applications of load at the same place or for different places having nominally the same conditions. What variations from the average stresses already reported may be expected to occur and what maximum stresses may be

TABLE 11.—VALUES OF THE RATIO OF THE STRESS AT ONE EDGE OF THE BASE OF RAIL TO THE MEAN OF THE STRESSES AT THE TWO EDGES. TIE IN PARTLY DECAYED CONDITION.

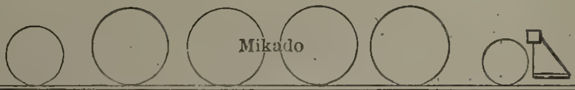


Speed, in miles per hour.	Instrument No.	85-Lb. Rail 6 In. × 8 In × 8-Ft. Ties Location I 6-In. Stone Ballast									
5	2	1·31	1.38	1.34	1.58	1.24	1.34	1.40	1.52	1.45	1.23
	3	1·19	1.07	1.36	1.49	1.19	1.22	1.36	1.23	1.23	1.13
	4	1.02	— 1.09	— 1.06	1.03	— 1.01	1.07	1.10	1.07	1.14	— 1.08
	7	1.14	1.19	1.11	1.30	1.04	1.13	1.12	1.13	1.17	1.17
15	2	1.24	1.28	1.30	1.39	1.23	1.26	1.34	1.34	1.53	1.00
	4	1.01	— 1.14	— 1.12	1.14	— 1.20	1.26	1.18	1.00	1.14	— 1.19
	7	1.02	1.13	1.09	1.37	1.08	1.10	1.13	1.14	1.11	1.33
25	2	1.26	1.31	1.29	1.36	1.26	1.30	1.35	1.35	1.32	1.25
	3	1.14	1.19	1.14	1.33	1.16	1.27	1.36	1.36	1.18	1.14
	4	— 1.37	— 1.43	— 1.22	— 1.04	— 1.45	— 1.16	— 1.08	— 1.61	— 1.10	— 1.45
	7	1.00	1.12	1.06	1.34	1.13	1.08	1.09	1.05	1.15	— 1.35
35	2	1.26	1.29	1.18	1.41	1.26	1.28	1.29	1.39	1.34	1.39
	4	— 1.14	— 1.51	— 1.19	— 1.08	— 1.15	— 1.28	— 1.24	— 1.47	1.06	— 1.26
	7	1.02	1.22	1.09	1.16	1.11	— 1.10	— 1.01	1.04	— 1.09	1.20
		85-Lb. Rail 6 In × 8 In. × 8-Ft. Ties Location L 15-In. Stone Ballast									
5	7	— 1.03	1.05	— 1.01	1.25	1.11	— 1.14	1.07	1.00	1.29	1.11
	4	1.28	1.33	1.34	1.37	1.26	1.23	1.35	1.32	1.18	1.17
	2	1.01	1.37	1.11	1.29	1.13	1.16	1.22	1.28	1.27	1.05
15	7	1.06	1.07	1.13	1.38	1.11	1.01	1.11	1.08	1.30	1.11
	4	1.15	1.09	1.09	1.31	1.20	1.22	1.37	1.25	1.31	1.19
	2	1.20	1.11	1.21	1.39	1.21	1.25	1.41	1.23	1.07	1.01
25	7	1.12	1.11	1.11	1.40	1.07	1.07	1.24	1.10	1.27	1.14
	4	1.19	1.09	1.06	1.42	1.11	1.25	— 1.40	1.25	1.41	1.23
	2	1.27	1.24	1.28	1.56	1.12	1.33	1.47	1.37	1.37	1.24
35	7	1.14	— 1.06	1.03	1.22	1.06	1.06	1.19	1.11	1.14	1.03
	2	1.32	1.28	1.44	1.48	1.15	1.27	1.50	1.28	1.31	1.30

expected are matters of importance. To arrive at a judgment on these questions will require a study of the variation in the observed values and of the probable errors of observation. Having determined the limiting error of observation which is probable and also the variation in the observed values which may be expected, a value of the probable limiting variation in the actual stress developed in the rail may be approximated, which will assist in judging what maximum stress may be expected to occur.

With the exception of the results given in the discussion on the Relation of the Stresses on the Two Sides of the Rail, the stresses recorded in the tables and on the diagrams represent the average of a large number of observations. For a given speed and a given wheel the results usually include the results of four instruments (each having a record for the inside edge of the rail and for the outside edge) for four runs at each of three adjoining locations on the track, say, counting out imperfect records, ninety observations in all; the average of the ninety observations is recorded as the value for the given wheel at the given speed. In the case of the tests on track at unsound ties and at low spots, the values given are the averages for one instrument, say, eight observations in all for each wheel at a given speed. For the comparison of stresses on the two sides of the rail the values given are the average of the records on a stremmatograph disc at one side of the rail at three locations, say, 12 observations at each speed and 48 observations for all speeds. It is evident that the individual observations will vary from the average result reported. Part of this variation will be due to errors in observation and part will represent actual variation in the stresses in the rail.

TABLE 12.—VALUES OF THE RATIO OF THE STRESS AT ONE EDGE OF THE BASE OF RAIL TO THE MEAN OF THE STRESSES AT THE TWO EDGES. TRACK WITH CINDER BALLAST.

Speed. in Miles per Hour.	85-lb Rail. 6"x 8"x 8'0" Ties. 6" Cinder Ballast. 							
5		1.24	1.22	1.31	1.26	1.14	1.09	
15		1.22	1.17	1.35	1.30	1.25	1.22	
25		1.13	1.24	1.45	1.32	1.27	1.05	
30		1.17	1.28	1.42	1.33	1.31	1.20	

Variations in the actual stress in the rail under nominally the same conditions may be due to differences in the way the locomotive wheels and car wheels are applied to the track in runs made at different times, as, for illustration, that produced by nosing or rolling or by variations in action of equalizers and springs; and they may be due to differences in the way the rail support (ties, ballast, etc.,) acts under changes in method of application of load, or to actual difference in the resisting action of the track support at two locations having seemingly the same conditions.

The sources of observational errors are (1) inherent characteristics in the design of the instruments, such as that in the stremmatograph, used in part of the 1915 tests; (2) looseness or play in bearings of record disc or somewhere in the clamps; (3) accidental conditions of operation, such as result from variable jolts or blows upon the track and from variable inertia effects in the instrument, and (4) errors in reading the record.

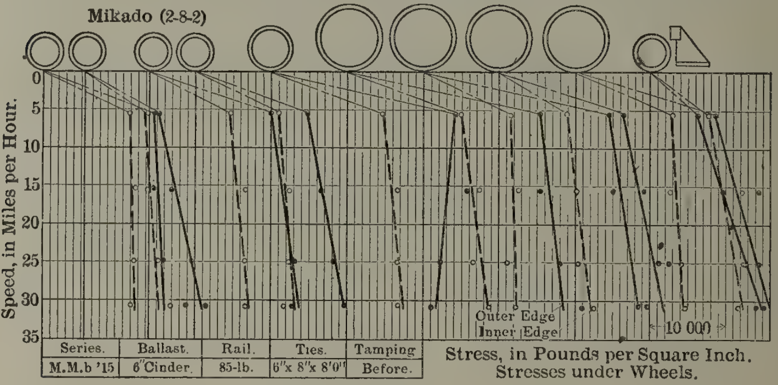
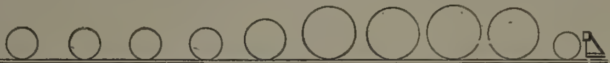

SPEED-STRESS DIAGRAM FOR EACH EDGE OF BASE OF RAIL.
MOVING-LOAD TESTS ON ILLINOIS CENTRAL RAILROAD WITH MIKADO LOCOMOTIVE.
TRACK WITH CINDER BALLAST.

Fig. 140.

The first mentioned source may give errors which are proportional to the stress, or nearly so. This sort of instrumental error was found in the stremmatograph used in part of the 1915 tests. It is believed that the design of the later instruments avoided errors of this sort of any magnitude. The second source of instrumental error gives variable accidental conditions in the use of the instrument. In the stremmatograph used, the presence of this condition when sufficient in amount could be detected by an examination of the record in the field and the instrument at once adjusted. Usually a variation in the action of the instrument equivalent to a stress of 600 lbs. per sq. in. could be detected. When it was seen that the variation amounted to more than 1000 lbs. per sq. in. the observation in question was discarded. For variations between these two general limits the observation was used and an allowance made, and the error from this source may not be expected to reach more than 600 lbs. per sq. in. for an individual observation. The variations from the third source, accidental conditions, frequently could be told from the characteristics of the record. When such a variation was marked, the observation was discarded. Notwithstanding this, there must exist in the results obtained from the records many variations which are due to accidental instrumental errors. Of the fourth source, that of reading the record, it has already been stated that in the early part of the work the average variation of the readings of the records made by either of two observers from the average reading of the two was 400 lbs. per sq. in., and that with later experience it is believed that there are very few readings in error more than 700 lbs. per sq. in. It may be noted that except for the first source the errors are as likely to be positive as to be negative and that except for the accidental instrumental errors they are largely independent of the magnitude of the stress; i. e., they are not greater for large stresses than for small ones.

TABLE 13.—VALUES OF THE RATIO OF THE STRESS AT ONE EDGE OF THE BASE OF RAIL TO THE MEAN OF THE STRESSES AT THE TWO EDGES FOR A SINGLE RUN ON A PREPARED TEST SECTION OF TRACK.



Speed, in Miles per Hour.	Instrument No.	85-lb. Rail. 6"x 8"x 8'0" Ties. 6" Stone Ballast.									
35	2	-1.06	-1.15	-1.23	-1.20	-1.25	-1.01	-1.16	-1.03	-1.13	-1.14
	3	-1.20	-1.13	1.07	1.00	1.17	1.15	-1.05	1.23	1.12	-1.05
	4	1.20	1.06	1.49	1.23	1.48	1.73	1.11	1.00	1.31	1.00

For the study of the variations a number of sets of test results were chosen at random. These included tests made with 85-lb. rail, 100-lb. rail and 125-lb. rail at the several speeds used, for each edge of base of rail and for the mean of the two edges. Diagrams were plotted for each set to show the relation between the magnitude of the variation from the mean and the number of observations. Fig. 141 shows one of these. The horizontal scale gives the variation from the average value of all the observations in per cent. of the average stress. The vertical scale gives the number of observations having a variation from the average value as great as or greater than the variation in question. At two points on these diagrams, such as A and B, a rather marked change in slope or break in the curve was found. While the several diagrams differed somewhat in the variation indicated at these characteristic points, the location of the points did not vary much from a little less than 10 per cent. of the number of observations, and the average magnitude of the variation at these points was ± 38 per cent. of the average stress. Outside of these points the number of observations corresponding to the variations became smaller, but there were always several values at or beyond ± 50 per cent., grouped in such a way as to seem well substantiated. Beyond these the observations were few and very irregularly placed. It may be stated, then, that in the sets studied 10 per cent. of the observations gave variations from the average stress of as much as ± 38 per cent. of the average stress and that always there were seemingly well-substantiated variations as great as ± 50 per cent.

In the several sets of results studied the mean variation of the individual observations from the average stress did not differ much; it averaged ± 22 per cent. Similarly the probable error of a single observation calculated by the theory of errors was nearly the same in all the sets, averaging ± 18 per cent. The diagrams, such as that in Fig. 141, are very similar in form to the curve of the probability integral, as they may be expected to be both because the errors of observation will follow the laws of chance and because the causes which produce variable stresses in the rail may also be expected to follow the laws of chance in the frequency of their application. The different sets of results which were studied had common characteristics; the variations at the line of 10 per cent. of number of observations (± 38 per cent.), the values of the mean variation from average stress, and the probable error differed little in the several sets. They were about the same at all speeds, for all wheels, and for both edges of the rail. This is all characteristic of accidental differences.

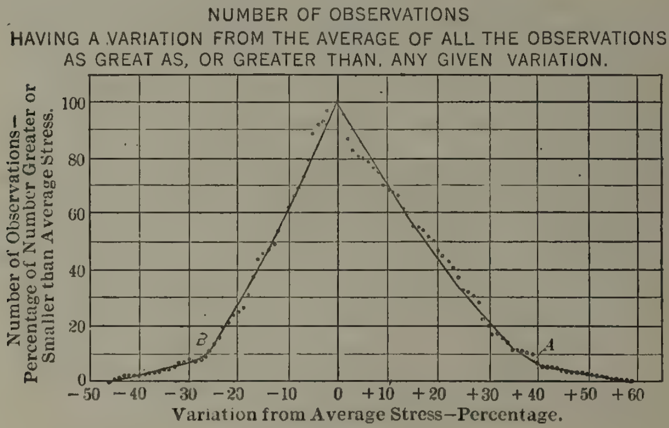


Fig. 141.

A consideration of the source and probable amount of the observational errors leads to the view that in 90 per cent. of the observations the error of a single observation will be less than 15 per cent. of the observed stress, and, of course, generally much less than this. This estimate takes into account both the observational errors that are independent of the magnitude of the stress and those that may be proportional to it; this limit of error may be somewhat too small for low stresses, such as 5,000 to 10,000 lbs. per sq. in., and somewhat too large for high stresses.

If, then, it be assumed that the error of observation for the observed stress at which there are 10 per cent. of the observations giving greater variation (B, in Fig. 141) is ± 15 per cent., and the variation of this observed stress from the average stress is taken as ± 38 per cent., it will be seen that the actual value of the stress in the rail which was observed as 1 + 38 per cent. may be as small as $\frac{1.38}{1.15} \times$ average stress, or 20 per cent. more than the average stress; and, of course, it might be as large as $\frac{1.38}{.85} \times$ average stress, or 62 per cent. more than the average stress. Similarly, for an observed stress 50 per cent. greater than the average stress, assuming that the limit of error of observation is ± 20 per cent., the actual stress in the rail may be as small as 25 per cent. more than the average stress. It may be asserted, then, that for nominally the same conditions of track and of load values of the stress in the rail 20 per cent. greater than the averages reported in the diagrams and tables, or even 25 per cent. greater, may be expected not infrequently, and of course by the theory of chance the probabilities are that these values may be exceeded considerably. In any effort to determine the maximum stress which may be developed in a rail this excess of the individual values of the stress over the value obtained by averaging results must be taken into account.

55. *Method of Estimating Maximum Flexural Stress in Rail for Given Conditions of Track and Loading.*—What maximum flexural stress may be developed in a rail under given conditions of track and loading is a matter of considerable interest. In making an estimate of the maximum stress it will be well to start with the average stress which may be expected at low speeds for the best conditions of track and introduce a series of factors covering the several sources of increase or variation from average stress at low speeds. Such an equation for flexural stress in the rail is

$$f = f_0\,(1+a)\quad(1+b)\quad(1+c)\quad(1+d)$$

$$= \begin{bmatrix}\text{average}\\ \text{stress at}\\ \text{5 m. p. h.}\end{bmatrix} \begin{bmatrix}\text{speed}\\ \text{factor}\\ \end{bmatrix} \begin{bmatrix}\text{lateral}\\ \text{bending}\\ \text{factor}\end{bmatrix} \begin{bmatrix}\text{condition}\\ \text{of track}\\ \text{factor}\end{bmatrix} \begin{bmatrix}\text{varia-}\\ \text{bility}\\ \text{factor}\end{bmatrix}$$

These factors have already been discussed to some extent. The average stress at 5 miles per hour would depend upon the locomotive loading and upon the nature of the track (rail, ties, ballast, etc.). For the "condition of track factor" the presence of low spots, defective ties, and other imperfect conditions must be considered, and even on fairly well-kept track this factor will need consideration. The Committee plans to discuss the magnitude of maximum stress for various conditions of track and loading in another report. It is evident that the maximum stress which may be developed in the rail under usual conditions of track and traffic may be much higher than the average stresses found for best track at low speeds, and that speed factor, lateral bending factor, condition of track factor, and variability factor should be recognized in making an estimate of the maximum stress to which the rail will be subjected.

56. *The Test Work on Ties, Ballast and Roadway.*—Considerable progress has been made in the experimental study of the action of ties, ballast and roadway. Tests on track have included the measurements of the amount of depression produced under load at various points below the tie and across and along the track and roadway. The measurement of pressure in ballast by means of the pressure capsule has given interesting data. Information has also been obtained with the recording pressure capsules. Measurement of the flexure of the tie has been made. Before completing tests on this part of the problem it was deemed wise to await the results of laboratory tests to determine the principles governing the distribution of pressure through ballast material, since this information would guide the extension of the tests and be useful in interpreting the data obtained.

The laboratory tests on transmission of pressure through ballast material have advantages over tests made in the field in that the conditions may be controlled more definitely and exactly and the tests repeated under identical conditions. In the experiments several ties are spaced as usual over a given depth of ballast and loads are applied on the rails. By having a number of pressure capsules inserted in the ballast at the different depths and positions at which the measurement of pressure is desired and then changing tie spacing and other variables, information bearing on the problem is obtained. Tests have been made with broken stone, gravel and sand as ballast material. Advantage has been taken of information and experience gained in tests on the transmission of pressure through granular material previously carried on in the laboratory. It seems evident from the experimental data obtained that quite definite laws govern the transmission and distribution of pressure through ballast materials and that these principles have a very direct bearing upon the effectiveness of different depths of ballast and different conditions of ties and tie spacing. The results of the investigation on ties, ballast and roadway will be presented in another report.

Respectfully submitted,

THE SPECIAL COMMITTEE ON STRESSES IN TRACK.

REPORT OF COMMITTEE XVII—ON WOOD PRESERVATION.

EARL STIMSON, *Chairman;*
F. J. ANGIER,
F. C. L. BOND (in Military Service),
E. H. BOWSER,
J. F. BURNS,
W. A. FISHER,
C. F. FORD,
C. J. GRAFF,
R. H. HOWARD,
C. H. R. HOWE,

C. M. TAYLOR, *Vice-Chairman;*
J. E. JOHNSON,
GEORGE E. REX,
H. STEPHENS (in Military Service),
E. A. STERLING,
LOWRY SMITH,
O. C. STEINMAYER,
C. H. TEESDALE,
DR. HERMANN VON SCHRENK,
J. H. WATERMAN,
Committee.

To the American Railway Engineering Association:

The following subjects were assigned by the Board of Direction to your Committee for study:

(1) Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, with especial reference to the subject-matter of "Water in Creosote." Special attention is also called to the necessity for revision of the arrangement of the specifications and statements.

(2) Report on the compilation of service test records and extend them to include treated timbers in bridges, docks and wharves. Include also a critical study of the records of service given by the zinc-chloride treatment and state definitely the results which may be obtained from that treatment.

(3) Report on the merits of water gas tar as a preservative, taking samples of the preservative from timbers which have been in service, in order to determine its quality.

(4) Co-operate with similar committees of other associations with the object of obtaining uniformity in practice and specifications, and report thereon.

Three meetings of the Committee were called as follows: The first on June 21, 1917, at Atlantic City, those present being C. M. Taylor, Vice-Chairman; E. H. Bowser, W. A. Fisher, C. J. Graff, E. M. Rhodes (representing E. Stimson). The second on October 19, 1917, at the Association rooms, Chicago, those present being C. M. Taylor, Vice-Chairman; F. J. Angier, E. H. Bowser, R. H. Howard, George E. Rex, E. A. Sterling, O. C. Steinmayer, C. H. Teesdale, E. M. Rhodes (representing E. Stimson). The third on January 21, 1918, at the Association rooms, Chicago. Meeting was not held on account of light attendance, and Association rooms closed by "Heatless Day" order.

Your Committee reports progress on the subjects assigned. But little work was accomplished during the year, as the members were widely scattered and busily engaged with their regular work, which the war conditions have made increasingly exacting. The work of the Committee is now of such a nature that it requires laborious experimental and research work and subsequent study to arrive at conclusions, all of which must be done by the individual effort of the members, so that under conditions such as prevailed during the past year but little can be accomplished.

There is offered as Appendix "A" to this report an interesting paper entitled, "Some Experiments Upon the Relative Penetration in Red Oak Cross-Ties of Lighter and Heavier Creosote Oils," by W. H. Courtenay, Chief Engineer of the Louisville & Nashville Railroad. While the Committee does not fully endorse its conclusions, the value of the paper is recognized, and it is submitted for the information of the Association.

It is the recommendation of the Committee that the program assigned for this year be continued the coming year.

OUTLINE OF WORK FOR 1918.

The Committee recommends a continuation of the study of subjects assigned for 1917, as follows:

(1) Make critical examination of the subject-matter in the Manual, and submit definite recommendations for changes, with especial reference to the subject-matter of "Water in Creosote." Special attention is also called to the necessity for revision of the arrangement of the specifications and statements.

(2) Report on the compilation of service test records and extend them to include treated timbers in bridges, docks and wharves. Include also a critical study of the records of service given by the zinc-chloride treatment and state definitely the results which may be obtained from that treatment.

(3) Report on the merits of water gas tar as a preservative, taking samples of the preservative from timbers which have been in service, in order to determine its quality.

(4) Co-operate with similar committees of other associations with the object of obtaining uniformity in practice and specifications, and report thereon.

In addition report on:

(1) The Preservative Treatment of Douglas Fir.

(2) Indicators for determining penetration of the preservative in freshly Burnettized ties and timbers.

Respectfully submitted,

The Committee on Wood Preservation.

Appendix A.

SOME EXPERIMENTS UPON THE RELATIVE PENETRATION IN RED OAK CROSS-TIES OF LIGHTER AND HEAVIER CREOSOTE OILS.

By W. H. Courtenay, Chief Engineer, Louisville & Nashville Railroad.

The specifications of the Louisville & Nashville Railroad Company for creosote oil for use in treating cross-ties, piles, and bridge timbers, are as follows:

"The oil must be the best obtainable grade of coal tar creosote; it must be a pure product of coal tar distillation, and must be free from admixture of oils, other tar or substances foreign to a pure coal tar; it must be completely liquid at 38 degrees C. and must be free from suspended matter; the specific gravity of the oil at 38 degrees C. must be at least 1.03. When, distilled according to the method recommended by Committee D-7, American Society for Testing Materials, 1915, Proceedings, using an 8-ounce retort, asbestos covered, with standard thermometer, bulb ½ inch above the surface of the oil, the creosote calculated on the basis of the dry oil shall not give more than a total distillate of 5 per cent. at 210 degrees C. The distillate between 210 and 235 shall not be less than 10 per cent. nor more than 20 per cent. The portion of oil distilling above 270 C. must be at least 25 per cent. and not less than 10 per cent. shall distill above 315 C. The residue above 355 C. must not exceed 40 per cent. The residue to be determined by weighing contents of retort after distillation. The residue above 355 C., if it exceeds 5 per cent., must be soft. For the purpose of examining the residue the contents of the retort must be allowed to remain a sufficient time before pouring out so that there will not be an excessive loss by evaporation. The oil shall not contain more than 2 per cent. of water."

In a conference held in the offices of the Railroad Company on May 21, 1917, with Messrs. S. R. Church and Stanley Woodward, of the Barrett Company, and John B. Lindsey and the writer, representing the Railroad Company, the shortage of oil was discussed generally and it was then claimed that if the above specifications were changed a greater quantity of oil could be furnished.

The changes suggested by the manufacturer's representatives were the following:

That the words "The distillate between 210 and 235 shall not be less than 10 per cent. nor more than 20 per cent." should be changed so as to read "The distillate between 210 and 235 shall not be less than 8 per cent. nor more than 20 per cent."

That the sentence reading "The residue above 355 C. must not exceed 40 per cent.," should be changed so as to read "The residue above 355 C. must not exceed 50 per cent."

The Railroad Company was averse to making the changes in the specifications without some tests being made in order to ascertain what difference, if any, there would be in the penetration of the heavier creosote oil in red oak ties from the penetration of the lighter oil. It was then agreed that the Barrett Company should ship to the Railroad Company's tie treating plant at Guthrie, Ky., about 50,000 gallons of creosote oil conforming to the specifications modified in accordance with the above suggestions.

It was agreed further that the Railroad Company after treating red oak ties with the 50,000 gallons of the heavier oil, would send samples of red oak ties treated with that oil to Mr. S. R. Church, of the Research Department of the Barrett Company, in order that he might determine whether the change of the specifications for the creosote oil is detrimental or beneficial or merely neutral.

He was requested to endeavor to ascertain whether there is any difference in the character of the oil which penetrates through the outer inch, the second inch from the outside, and the third inch from the outside of the cross-tie, the purpose being to determine whether there is any separation of the oil in its penetration through these three zones and whether the heavier oil has the effect of blocking the pores of the wood in the outer fibers, preventing the passage of the oil to the fibers nearer the center of the tie.

The following paper entitled "Notes on the Absorption and Penetration of Creosote Oils used in Wood Preservation, particularly as regards the possible Separation of the Creosote into Light and Heavy Portions due to a Filtering Action of the Wood," was furnished by Mr. S. R Church, Manager Tar and Oil Division of the Barrett Company.

NOTES ON THE ABSORPTION AND PENETRATION OF CREOSOTE OILS USED IN WOOD PRESERVATION—PARTICULARLY AS REGARDS THE POSSIBLE SEPARATION OF THE CREOSOTE INTO LIGHT AND HEAVY PORTIONS DUE TO A FILTERING ACTION OF THE WOOD.

By S. R. Church, Manager, Research Department, The Barrett Company.

The question of the relative penetration of Creosote Oils into woods has been the subject of considerable discussion. In this connection it has frequently been held that the wood itself had an appreciable filtering action and separated the Creosote into light and heavy portions, as a result of which only the lighter portions penetrated to the interior, the heavier portions remaining in the outer zones and even interfering materially with the penetration of the lighter portions because of a "plugging" action which prevented the ready passage of the oil to the interior of the wood. During May, 1917, the specifications of the Louisville & Nashville Railroad Company for Creosote Oil were under consideration. At a conference attended by W. H. Courtenay, Chief Engineer, and J. B. Lindsey, Superintendent of Timber Treating Plants of the Louisville & Nashville Railroad, and Stanley Woodward and S. R. Church, of The Barrett Company, it was decided that it would be of mutual advantage to treat a number of Red Oak Cross-ties using two different grades of Creosote Oils, following which the Creosote would be extracted from various parts or zones of the ties, and analyzed in an endeavor to ascertain whether there was any difference in the character of the oils which penetrated into the outer inch, into the second inch and into the third inch from the outside. The description of these tests together with the results obtained is the pupose of these notes.

Treatment of Cross-Ties.

Red Oak Cross-ties were treated at the Creosoting Plant of the Louisville & Nashville Railroad at Guthrie, Ky., and the treatment was in accordance with the company's standard practice, i. e., by the Full-Cell process, using approximately eight (8) pounds of Creosote Oil per cubic foot of wood.

Creosote Oil Used.

Two grades of Creosote Oils were used, these were numbered Nos. 7 and 8. The difference between these oils as shown by the requirements of their specifications is as follows:

	Oil No. 7	*Oil No. 8*
Distillate between 210 and 235° C.—not less than.......	10.0%	8.0%
Distillate between 210 and 235° C.—Not more than......	20.0%	20.0%
Residue above 355° C.—not more than..................	40.0%	50.0%

Complete analysis of the Oils is given in the tabulations which are appended.

Choice of Tie Sections.

Eight ties were selected, four of which had been treated with Oil No. 7 and four with Oil No. 8. A one-foot section was taken from each of these ties, this was cut near the rail base, hence it was well within the tie and therefore escaped the full effect of longitudinal penetration. These eight sections were marked for identification by lettering as follows: 7A, 7B, 7C, 7D, and 8A, 8B, 8C, 8D, so as to correspond to the Oils Nos. 7 and 8.

Separation of Tie Sections Into Zones.

Side of Radial Zones.—Three zones one inch in thickness were taken from sections 7A, 7B, 8A and 8B. These zones numbered 1, 2 and 3, were cut as is shown in the Drawing A. The two corresponding zones from each section were united for the tests. It was suggested that the effect of end-on or longitudinal penetration might offset the results. To overcome this each succeeding zone was cut in one inch from the end.

End-On or Longitudinal Zones.—In line with the preceding it was thought advisable to determine if possible the variations in longitudinal penetration, therefore two-inch cuts were made from each end of sections 7C, 7D, 8C and 8D. See Drawing A. It was impossible at the time to choose these cuts so that the ends of the four sections would be in the same relative position as regards their distances from the actual tie ends.

Extraction of Creosote from Tie Sections.

Reduction to Sawdust.—The blocks of wood representing the various zones from the tie sections were reduced to a coarse sawdust by means of a circular saw, at a neighboring planing mill. The sawdust was collected by a suction pipe and was kept in tightly covered cans until ready for extraction. While no record was kept of the volumes or weights of the blocks, there was noticeably but little loss in material during this operation.

Extractor.—The extractor was assembled in the laboratory from such apparatus as was available. It consisted of a two-gallon cylindrical tin can, a two-liter round-bottom glass distilling flask, and a water-cooled reflux condensor. The lower end of the can was connected to the top of the flask by a piece of three-quarter inch glass tubing, the upper end of this tubing was connected to a small tube which was bent at right angles and continued to the top of the can. The layer of the solvent in the can was automatically maintained at a height of about three inches by means of a syphon made from glass tubing bent in the form of a "U." This was sealed into the glass tubing which connected the bottom of the can with the flask and which continuing under the surface of the Benzol in the flask served as the lead for the extracted material from the can to the flask. (See photo.) In operation the sawdust was placed in a cloth bag and then put into the can. Benzol was placed in the flask, the tube connections were made tight and the operation carried on over a steam bath, the condenser worked very well and but little of the Benzol was lost by evaporation. In general around 2,000 grams of sawdust were used, and the operation continued until the syphoned extract flowed colorless. This required from four up to ten or twelve hours.

Recovery of Creosote Oil.—The extract was placed upon a steam bath and the Benzol evaporated, the last traces were removed by direct heat. In all cases there was a sudden break in the distillation at about 120 degrees C. with but a very slight discoloration of the Benzol distillate. The oil recovered was weighed and then analyzed.

Determination of Water in Creosote Wood.

The extracted wood was spread out in pans and then weighed. These weights were found to differ from the original weight of the creosoted wood less the recovered oil, by from 10 to 20 per cent. water. Determinations on this extracted sawdust were unsatisfactory; it was therefore decided to determine the original water content of the sawdust. This was done by placing 200 grams of the original sawdust in a copper still with a Xylol which had a boiling point of from 135 to 145 degrees C. The distillation was carried on until no further water came over under a temperature of 140 degrees C.

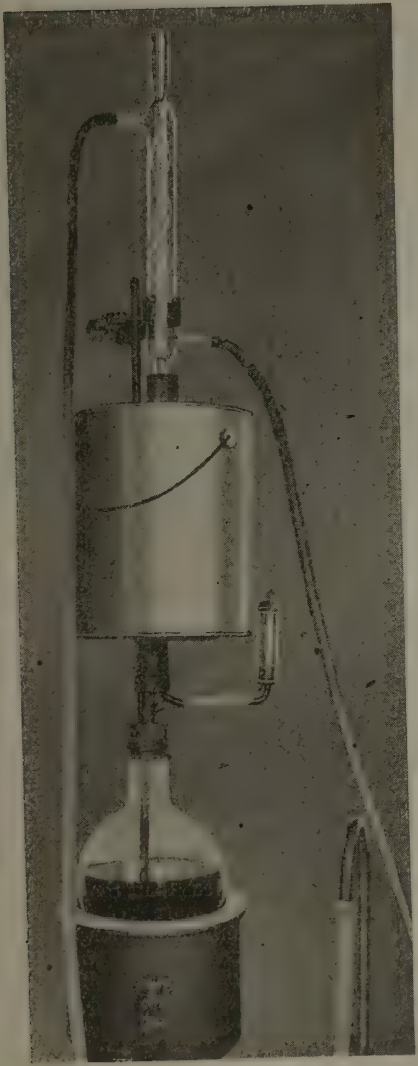


FIG. 1.—EXTRACTOR.

Solvent Action of Benzol Upon Materials Other Than Creosote in the Sawdust.

It was desided to determine if there was any appreciable result due to the solvent action of the Benzol upon constituents of the wood other than the Creosote Oil with which they were treated. Sections of uncreosoted Red Oak ties were taken and reduced to sawdust; this sawdust was then extracted in the same manner as was followed in the above work. The results obtained were as follows:

	Sample No. 1		*Sample No. 2*	
Original Wood	935 grams	100.0%	830 grams	100.0%
Water Content	140 "	15.0%	119 "	14.2%
Wood Pulp	789 "	84.4%	705 "	85.0%
Dry Extract	4 "	0.4%	4 "	0.5%
Loss	2 "	0.2%	3 "	0.3%

The dry extract was brown in color and of a waxy consistency. These tests indicate that while there is a small amount of material extracted from the wood by the benzol, that this should not have any material action upon the general results of the experiments in hand.

Results.

Previous to cutting the sections of the cross-ties into zones, they were inspected. The surfaces of all were found to be reasonably clean and dry and there was no visible evidence of material such as free carbon to indicate that the oils had been separated into different portions by any filtering action of the wood. It was noted, however, that the sections treated with the heavier creosote, that is with No. 8 Oil, were all darker in color than those treated with the No. 7 Oil.

The results of the tests are tabulated in Tables I and II. Curves for the Retort Distillations are given in Tables III and IV, these curves when plotted direct were rather confusing, because they were superimposed upon each other; as here plotted a sliding scale was used for the percentages of distillation with the rsult that the curves appear separate and distinct and tend to a clearer presentation.

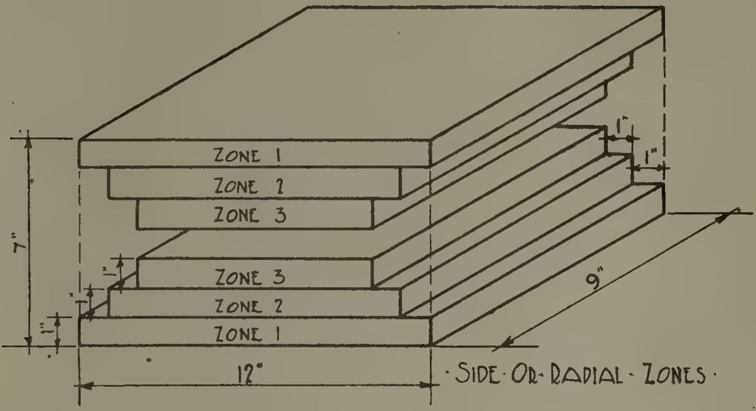
Discussion of Results.

Quantity of Creosote Absorbed by the Various Zones.—The outer zones of the sections contain appreciably more oil than the inner zones, which was naturally to be expected. However the difference between the absorptions for the outer and inner zones is decidedly less with the Creosote No. 8 than with the Creosote No. 7. This more favorable result with the heavier oil is rather unexpected. Assuming, however, that all the treatments at the creosoting plant were carried on in exactly the same manner, then the conclusion is reached that the ties chosen from the treatments with the No. 8 Oil were more readily treated, because of better seasoning or because they contained a larger proportion of sapwood, or else the Creosote No. 8, for some reason that remains obscure, is the better oil as regards penetration and absorption.

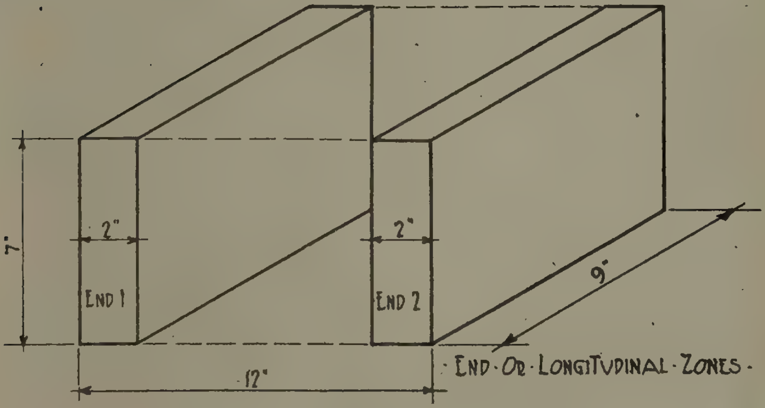
Quality of Creosote Oils in the Various Zones.—The quality of the oil extracted from the different sections is shown by the analyses as given in Tables I and II. From these results it is apparent that there are no consistent differences which would indicate changes in the quality of the oil due to any filtering action by the wood or to any other decided causes. Small differences do exist, but these can in general be accounted for by the unavoidable errors due to manipulations in analytical work. The results show that for the same oil there are no appreciable differences as taken from different parts or zones of the treated sec-

~SEPERATION·OF·TIE·SECTIONS·INTO·ZONES~

DIAGRAM "A"



·SIDE·OR·RADIAL·ZONES·



·END·OR·LONGITUDINAL·ZONES·

tions. There is, however, a slight difference between the original oils and the extracted oils, the latter show an average increase in residue above 355 degrees C. of about 4.0 per cent. with a slight increase in its float test; there is also a slight increase in the specific gravity and the coke test. These variations between the original and the extracted oils are due possibly to a cracking or carbonization action brought about by the continued heating of the oils during the process of extraction. The effect of this continued heating under the conditions of the present tests was not determined.

Conclusions.

Since the Red Oak cross-ties treated with Creosote Oil No. 8 showed appreciably better absorption and penetration in the various zones examined than did those treated with Creosote Oil No. 7, it is evident that the heavier oil does not, under the conditions described, present any new treating problems. With due consideration to the limitation of the present work the results warrant the statement that there is no appreciable difference in the character of the creosote oils extracted from the outer inch, from the second inch or from the third inch zones of the creosoted red oak cross-ties. This statement holds for both Creosote Oils Nos. 7 and 8, and therefore leads to the conclusion that there is no measurable filtering action by the wood upon either of the two oils considered.

As the treatment of the ties with the No. 7 oil and with the No. 8 oil, referred to in Mr. Church's notes, was done under the supervision of Mr. John B. Lindsey, Superintendent of Timber Treating Plants, Louisville & Nashville Railroad Company, Mr. Church's notes were referred to Mr. Lindsey for comments and any criticisms which he might have to make.

The following discussion of Mr. Church's report was prepared by Mr. Lindsey.

TABLE - I

CREOSOTE OIL - #7

	Original	SIDE OR RADIAL ZONES						END OR LONGITUDINAL ZONES			
	Creosote	Section - 7A			Section - 7B			Section - 7C		Section - 7D	
	Oil	1"	2"	3"	1"	2"	3"	1.	2.	1.	2.
EXTRACTION											
Creosote . %		15.8	2.9	3.1	16.2	8.2	7.5	15.5	14.4	13.5	11.7
Water %		14.0	25.0	#	#	20.0**	20.0**	#	#	12.0	18.5**
Wood Pulp %		66.9	49.3	68.9	75.4	70.7	70.7	75.0	75.0	73.3	71.8
Loss or Gain %		-3.3	-22.8*			-1.1	-1.8			-1.2	+2.0
ANALYSES			##	X			X				
Specific Gravity 38/155°C	1.092	1.086	1.096	1.088	1.097	1.097	1.088	1.095	1.091	1.104	1.099
Coke %		3.6	5.3	4.0	4.1	4.4	4.0	3.6	4.6	3.7	5.2
Float - Seconds at 70°C		40.8 40.8		43.8 44.4	37.2 37.2	34.8 35.4	43.8 44.4	40.2 40.8	36.6 36.6	37.2 38.4	40.2 39.6
Retort Distillation %											
Totals - 170°C	-	2.6		-	-	-	-	1.4	1.4	-	-
" - 200	1.1	4.0		1.3	-	-	1.3	2.7	2.6	-	-
" - 210	1.9	5.0		2.9	-	-	2.9	3.0	3.5	-	0.5
" - 235	11.9	10.3		9.9	7.0	6.9	9.9	7.4	8.6	3.4	6.6
" - 270	33.5	28.2		28.3	25.3	26.0	28.3	21.9	23.7	19.6	22.5
" - 315	47.9	42.1		43.0	41.7	41.4	43.0	38.3	38.8	36.7	37.4
" - 355	62.8	60.9		61.9	60.3	58.0	61.9	58.2	58.2	55.6	56.6
Residue above 355	37.2	39.1		38.1	39.7	42.0	38.1	41.8	41.8	44.4	43.4
COLUMN	1	2	3	4	5	6	7	8	9	10	11

NOTES - * Loss due largely to breakage of Extraction Apparatus
** Water determination on extracted sawdust - not on original
# Water determination not made
## Insufficient oil for complete analyses
X Combined oil from the 3" Zones of Sections 7A and 7B.

TABLE - II

CREOSOTE OIL - #8

	Original Creosote Oil	SIDE OR RADIAL ZONES						END OR LONGITUDINAL ZONES			
		Section - 8A			Section - 8B			Section - 8C		Section - 8D	
		1"	2"	3"	1"	2"	3"	1.	2.	1.	2.
EXTRACTION											
Creosote %		28.6	19.4	16.2	18.8	13.0	13.4	9.4	11.8	13.0	13.7
Water %		12.5	15.0	20.0	14.0**	21.5	20.0	3.6	2.8	18.5**	19.9**
Wood Pulp %		57.9	57.1	61.8	67.2	58.0	52.4	70.0	71.0	69.4	66.6
Loss or Gain %		-1.0	-8.5*	-2.0	0.	-7.5	-14.2	-17.0*	-14.4**	0.9	0.2
ANALYSES											
Specific Gravity 38/155°C	1.097	1.104	1.107	1.100	1.108	1.105	1.098	1.115	1.115	1.110	1.115
Coke %	2.83	3.4	3.6	3.4	3.5	3.0	3.1	4.1	5.0	3.6	4.3
Float Seconds at 70°C %	33.6 33.6	37.2 37.2	38.4 39.0	34.2 34.2	36.6 37.2	39.0 39.0	40.2 40.8	42.0 41.4	44.4 44.4	42.0 41.4	46.2 45.6
Retort Distillation %											
Totals - 170°C	-	0.3	-	0.6	-	-	0.7	-	-	-	-
" - 200	-	1.3	-	1.8	-	-	2.3	-	-	-	-
" - 210	-	2.1	-	2.5	0.5	0.5	3.5	-	-	0.6	-
" - 235	8.7	10.1	5.2	7.5	6.0	5.8	8.9	4.9	5.1	5.6	4.7
" - 270	26.2	22.1	21.1	23.7	20.2	22.9	23.4	16.7	16.4	19.8	14.3
" - 315	38.5	35.1	33.2	35.3	32.7	34.5	35.8	28.2	29.8	32.0	27.6
" - 355	53.8	50.3	49.0	51.2	48.6	50.8	52.7	46.6	47.9	49.6	45.6
Residue above 355	46.2	49.7	51.0	48.8	51.4	49.2	47.3	53.4	52.1	50.4	44.4
COLUMN	1	2	3	4	5	6	7	8	9	10	11

NOTES - * Loss due largely to breakage of Extraction Apparatus
** Water determination on extracted sawdust - not on original

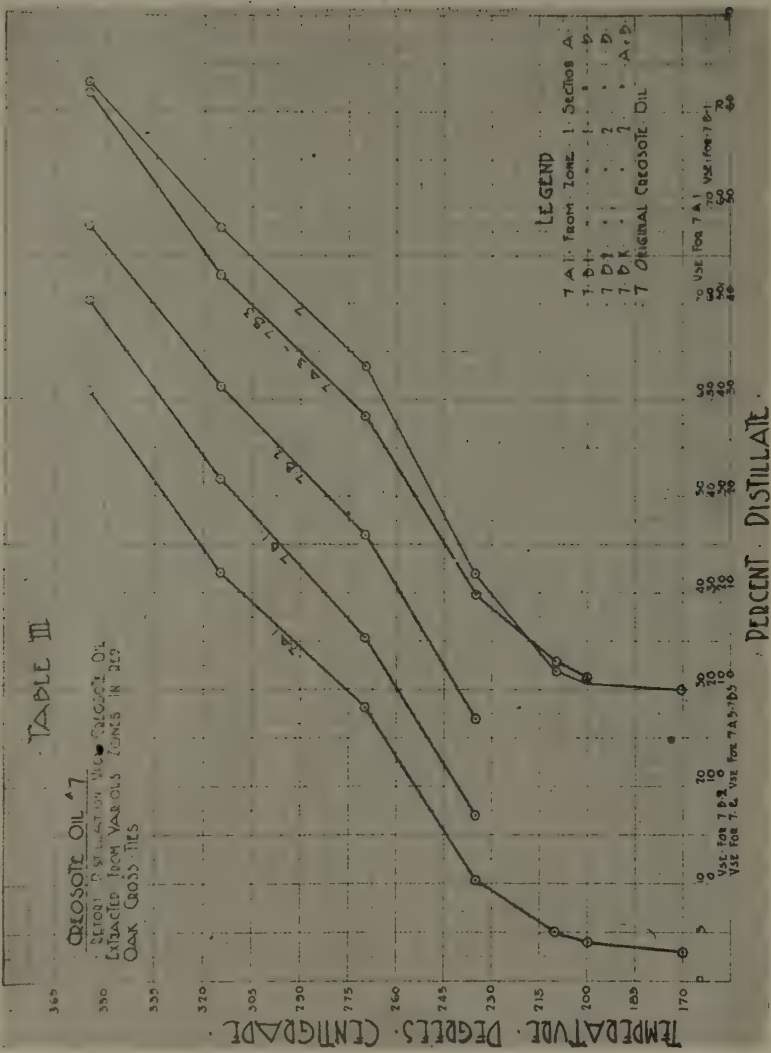


TABLE III
CREOSOTE OIL #7
RETORT DISTILLATION OF CREOSOTE OIL
EXTRACTED FROM VARIOUS ZONES IN RED
OAK CROSS TIES
LEGEND
7 A 1 FROM ZONE 1 SECTION A
7 B 1 " " 1 " B
7 D 2 " " 2 " D
7 D K " " 2 " A & D
7 ORIGINAL CREOSOTE OIL
7
7 A 1 - 7 B 1
7 D 2
7 D 1
7 B 1
TEMPERATURE · DEGREES · CENTIGRADE ·
365
350
335
320
305
290
275
260
245
230
215
200
185
170
PERCENT · DISTILLATE ·
0
5
10
20
30
40
50
60
70
USE FOR 7 D 2
USE FOR 7 & USE FOR 7 A 5 · 7 D 5
USE FOR 7 A 1
USE FOR 7 D 1

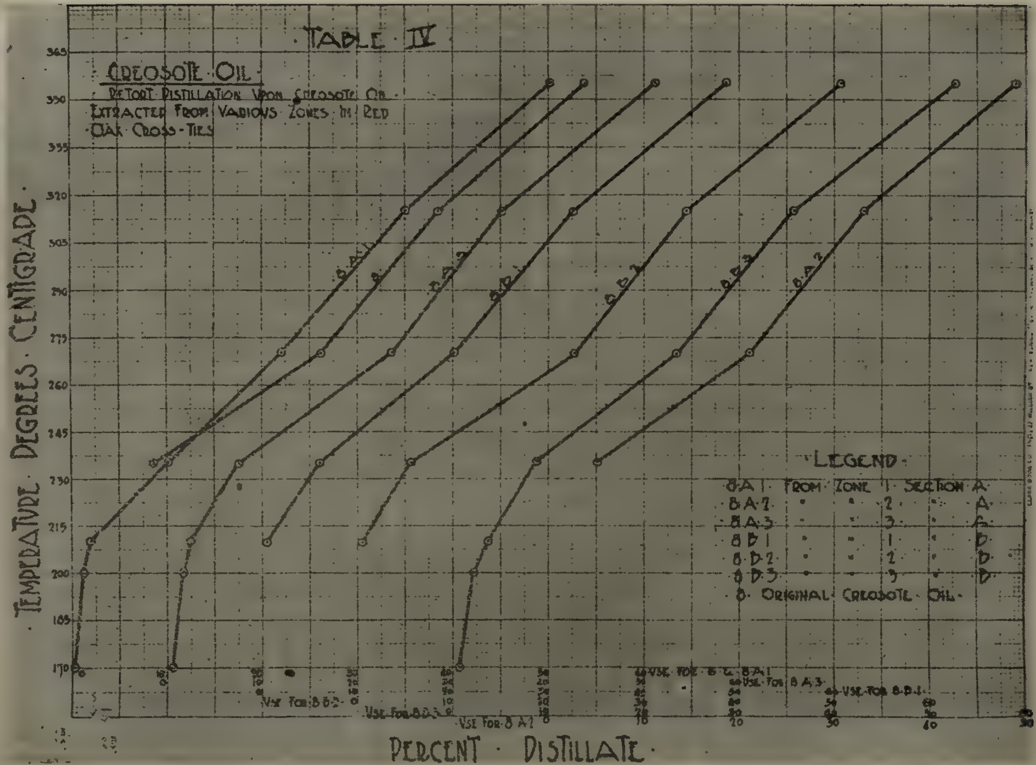


TABLE IV
CREOSOTE OIL
RETORT DISTILLATION UPON CREOSOTE OIL EXTRACTED FROM VARIOUS ZONES IN RED OAK CROSS-TIES
LEGEND
8 A 1 FROM ZONE 1 SECTION A
8 A 2 " " 2 " A
8 A 3 " " 3 " A
8 D 1 " " 1 " D
8 D 2 " " 2 " D
8 D 3 " " 3 " D
8 ORIGINAL CREOSOTE OIL
8 A 1
8
8 A 3
8 D 1
8 D 2
8 D 3
8 A 2
365
350
335
320
305
290
275
260
245
230
215
200
185
170
USE FOR 8 D 2
USE FOR 8 D 3
USE FOR 8 A 2
USE FOR 8 & 8 A 1
USE FOR 8 A 3
USE FOR 8 D 1
10
20
30
40
50
TEMPERATURE · DEGREES · CENTIGRADE ·
PERCENT · DISTILLATE ·

DISCUSSION OF TESTS MADE BY THE BARRETT COMPANY TO DETERMINE THE ABSORPTION AND PENETRATION OF TWO GRADES OF CREOSOTE OIL IN RED OAK CROSS-TIES.

Ties Used in Tests.

Red oak and black oak ties were selected for the tests for the reason that all seasoned ties the Railroad Company had in stock to treat in 1917 were of these species. These ties had been air-seasoned approximately 9 months at the tie plant yard at Guthrie, Ky., before treatment.

Treatment.

Approximately 700 — 7″ × 9″ × 8′ 6″ ties were creosoted with 8 lbs. per cubic foot full cell in one of the plant cylinders with No. 7 oil and the same number of ties were similarly treated in the other cylinder with No. 8 oil. Record of treatment of these ties follows:

Treatment with No. 7 Oil.	*Treatment with No. 8 Oil.*
2 Hours steaming, 15 lbs. pressure	2 Hours Steam, 15 lbs. pressure
1 Hour low vacuum	1 Hour low vacuum
3 Hours oil pressure, 140 lbs.	3½ Hours oil pressure, 135 lbs.
180° F. temperature of oil	180° F. temperature of oil
3.43 gals. of oil per tie injected	3.39 gals. oil per tie injected

It will be noted it took 30 minutes longer to make the oil injection with the heavy No. 8 oil than with No. 7 oil. This may have been due partly to difference in seasoning of the two charges of ties.

Seven ties were selected from the two cylinder charges for the tests, three ties treated with No. 7 oil and four ties treated with No. 8 oil. Fourteen one-foot sections were cut from these ties, each section beginning 18 inches from end of tie. Four sections treated with No. 7 oil and the same number treated with No. 8 oil were selected from the fourteen sections, the sections selected being those where there was a satisfactory oil penetration at least three inches from the surface of tie.

Object of Tests.

The Railroad Company wished to determine if the heavier oil, No. 8, would penetrate red oak satisfactorily and to make comparison with penetration of oil in ties treated with No. 7 oil. Also to determine if the wood fiber had any filtering effect on the oil resulting in the oil near the surface being heavier than the oil injected farther in the tie.

At the present time it is possible to secure only heavy gravity creosote oils in large quantities. The L. & N. Railroad engineers consider the further investigation of many other factors affecting creosote oil specifications necessary before adopting standard oil specifications. Railroad timbers have been treated at the West Pascagoula plant of the Louisville & Nashville Railroad since 1876. Most of the piling and timbers treated thirty to forty years ago are still in a good state of preservation. In the case of piling placed in the salt waters of the Gulf of Mexico it has been found necessary to further protect from attacks of marine borers the creosoted piles below the water line, after approximately 15 years' service, by terra cotta and iron piping filled with sand. The creosote oils used at the West Pascagoula plant up to 1905 were principally low gravity English oils. According to the oldest records preserved (1901-2) the specific gravity of these English oils was 1.925 with only 20 per cent. to 30 per cent. residue after distillation to 270 Centigrade. The U. S. Department of Agriculture, Bulletin 227, on page

28 gives following table showing pounds per cubic foot of the different coal tar fractions it is necessary to inject into timber to preserve timber from attacks of fungus *Fomes Annosus:*

Coal tar creosote, Grade C	.343
Coal tar creosote, Fraction I, distillate to 205 C.	.187
Coal tar creosote, Fraction II, distillate 205—250 C.	.140
Coal tar creosote, Fraction III, distillate 250—295 C.	.203
Coal tar creosote, Fraction IV, distillate 295—320 C.	2.06
Coal tar creosote, Fraction V, residue above 320 C.	20.59

It therefore appears the low boiling fractions of coal tar creosote are much more poisonous to the fungi of decay than the higher fractions, particularly fraction 5. On the other hand the high boiling fractions are less volatile and hence are more permanent and durable in the timber.

Tests begun in 1911 by the U. S. Forest Service on a large number of pile sections treated with the different fractions of coal tar creosote and with coal tar creosote, placed in salt water at Pensacola, Fla., indicate that fraction 4, fraction 5 and coal tar creosote are the most effective in protecting piling in salt waters from marine borers, the specimens treated with the lighter oil, fractions 1, 2 and 3 being badly attacked by the borers, especially fractions 1 and 2.

Comments.

1. On account of the small number of ties on which these tests were conducted no very definite results can be established.

2. The test ties of each oil treatment were creosoted with nearly 700 other ties. Hence the ties selected with at least three-inch oil penetration may have had considerably heavier treatment than 8 lbs. of oil per cubic foot.

3. The difference between the absorptions in the outer and inner zones being less with creosote No. 8 than with creosote No. 7 is probably due to inequalities in the treatment. If the four test ties with No. 8 oil and the three test ties with No. 7 oil had been treated separately in a small test cylinder, each tie given only 8 lbs. per cubic foot, more definite comparison could be made as to the relative penetration of the two oils.

As is well-known, when seven hundred ties are treated in one charge there is great difference in the oil penetration in the different ties, some ties receiving two or more times as much oil as some of the other ties.

4. As previously stated, red oak and black oak ties were selected for the tests for the reason that all ties to be treated at the Guthrie Tie Plant in 1917 were of these species. Red oak and black oak being ring porous woods, a large portion of the oil injection penetrates through the ends of the ties passing through the open vessels or "pores." For this reason tests on pine ties and some of the diffuse porous woods like beech and gum would give better evidence if there is any filtering action by the wood when creosote oil, especially heavy oils or mixtures of oil and tar, are injected into wood.

While the results of Mr. Church's investigation may not be conclusive on account of the relatively small number of samples which were tested, and also on account of the well-known widely varying penetration due to difference in density of the timber in different ties, they are of value and may offer suggestions for further experiments of the same general character.

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Construction
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Bond Wires.
Bridge Timbers.
Buildings.
Bumping Posts.

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Crossing Gates.
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Switch-Ties.
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